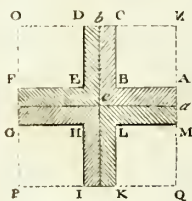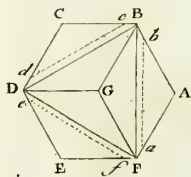W5

Pl. I.

Fig. 5.

Fig. 3.

Fig. 2.

Fig. 1.

Fig. 6.

Fig. 4.
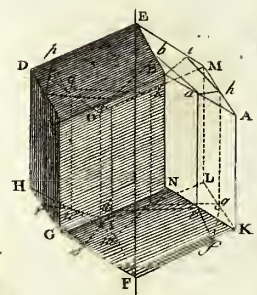
Fig. 12.

Fig. 7.
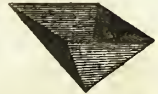
Fig. 11.

Fig. 15.

Fig. 16.

Fig. 18.

Fig. 8.
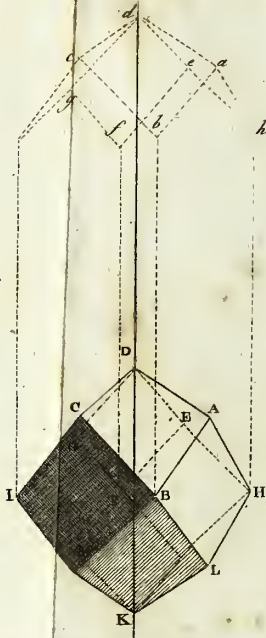
Fig. 19.

Fig. 9.
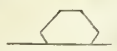
Fig. 10.

Fig. 13.

Fig. 14.
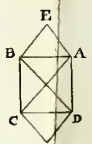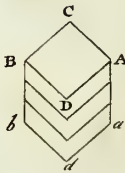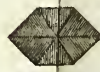
Fig. 17.
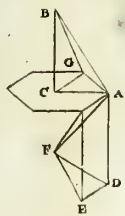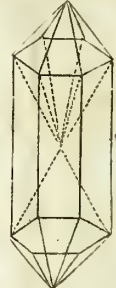
PHYSICAL AND CHEMICAL

E S S A Y S;

TRANSLATED FROM THE ORIGINAL LATIN OF

Sir TORBERN BERGMAN,

KNIGHT OF THE ORDER OF WASA, PROFESSOR OF
CHEMISTRY AT UPSAL, &c. &c. &c.

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AT DUBLIN.

TO WHICH ARE ADDED

NOTES AND ILLUSTRATIONS,

BY THE TRANSLATOR.

VOL. II.

Hominis imperium in Res, in folis Artibus & Scientiis ponitur. Naturæ enim non imperatur, nifi parendo —— Si quis depravationem Scientiarum & Artium ad malitiam & luxuriam & fimilia objecerit; id neminem moveat. Illud enim de omnibus mundanis bonis dici poteft, Ingenio, Fortitudine, Viribus, Forma, Divitiis, Luce ipfa & reliquis. Recuperet modo genus humanum jus fuum in Naturam, quod ei ex dotatione divina competit; & detur ei copia; ufum vero recta ratio & fana religio gubernabit.

BACO DE VERULAMIO.

TO THE

ILLUSTRIOUS

ROYAL SOCIETY

FOR THE PROMOTION OF SCIENCE

AND POLITE LITERATURE

AT BERLIN,

THIS VOLUME IS DEDICATED

BY THE AUTHOR,

WHO WAS CHOSEN A FELLOW

WHEN HE WAS PRESENT.

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Philosophia naturalis scripta est in maximo isto libro, qui continue nobis ante oculos jacet apertus (universum hoc ajo), sed nihil aut in eo legi, aut intelligi poterit, nisi prius addiscatur idioma, quo exaratum est. Characteres ejus sunt triangula, circuli & aliæ figuræ geometricæ. GALILÆUS.

XIII. Of SILICEOUS EARTH. p. 26.

Sunt aliquot quoque res, quarum unam dicere causam Non satis est. LUCRETIUS.

A 3   § 3. *Its*

XIV. Of the HYDROPHANOUS STONE. p. 57.

Heu prodigioſa ingenia, quot modis auximus pretia rerum.
PLINIUS.

XV. Of the EARTH of GEMS. p. 75.

In arctum coacta rerum naturæ majeſtas. PLINIUS.

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Et alias invenio (gemmarum ardentium) *differentias; unam, quæ purpura radiet, alteram, quæ Cocco; a fole excalefaƈtas aut digitorum attritu, paleas & chartarum fila ad fe rapere.*
                                            PLINIUS.

XVII. Of the FULMINATING CALX of GOLD. p. 134.

Quælibet res nihil præftare poteft præter id, quod in fe eft & continet. GEBER.

A 4   § 6. *Different*

XVIII. Of PLATINA. p. 166.

Multa sæculis tunc futuris, cum memoria nostri exoleverit, reser-
vantur; veniet tempus, quo ista, quæ nunc latent, in lucem
dies extrahet & longioris ævi diligentia. Rerum enim na-
tura sacra sua non simul tradit; initiatos nos credimus, in
vestibulo ejus hæremus; illa arcana non promiscue, non
omnibus patent, reducta & interiori sacrario clausa sunt;
involuta veritas in alto latet. SENECA.

§ 7. *Pro-*

XIX. Of the WHITE ORES of IRON.
p. 184.

Usus & impigræ simul experientia mentis.
Paulatim docuit pedetentim progredientes.
            LUCRETIUS.

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Est quodam prodire tenus, si non datur ultra. HORATIUS.

§ 4. *Eli-*

XXI. Of Arsenic. p. 274.

*Quam pulchrum est, in principiis, in origine rerum
Defixisse oculos & nobile mentis acumen !
Pervolat huc Sapiens.*   Anti Lucretius.

XXII. Of the ORES of ZINC. p. 311.

Ex omnimoda experientia, primum inventio causarum & axiomatum verorum elicienda est : & lucifera experimenta, non fructifera, quærenda. Axiomata autem recte inventa & constituta Praxin non strictim, sed confertim instruunt ; & operum agmina ac turmas post se trahunt.

F. BACO DE VERULAMIO.

XXIII. Of METALLIC PRECIPITATES.
P. 349.

*Nec manet ulla sui similis res; omnia migrant,
Omnia commutat Natura & vertere cogit.* LUCRETIUS.

XXIV. Of the ART of ASSAYING in the HUMID WAY.

Abdita quid prodest generosa vena metalli
Si cultore caret ?   LUCANUS.

XXV. Of

XXV. Of the BLOW-PIPE; and its Use in the Examination of Bodies, particularly Minerals. p. 463.

Scientia a rebus occultis & ab ipsa natura absconditis ad usum communem est adducenda. CICERO.

Intumescent

DISSER-

DISSERTATION XII.

OF THE

FORMS OF CRYSTALS,

PARTICULARLY THOSE OF

THE SPATHACEOUS KIND.

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§ 1. *Infinite Variety of the Forms of Crystals.*

CRYSTALS are bodies which, though destitute of organic structure, yet externally resemble geometrical figures, more or less regular. If we attend to the numerous collections of these, we shall be ready to conclude, that nature has effectually eluded our research by the infinite variety; for frequently bodies widely differing in their nature and properties resemble one another in figure; and, on the contrary, those which are exactly alike in properties put

on external appearances entirely different;
yet, upon a careful examination and com-
parifon of this variety of figures, we fhall
find, that a great number of them, though
their furfaces differ with refpect to their
angles and fides, may be derived from and
referred to a very fmall number of fimple
figures.

Unlefs thofe figures, which are not im-
properly called primitive, be thoroughly in-
veftigated, the whole doctrine of cryftalliza-
tion will ftill continue to be, as it has been
heretofore, a perfect chaos; and thofe who
undertake the defcription or methodical dif-
tribution of cryftallized bodies, will in-
evitably lofe their labour. For a feries of
years I have confidered this intricate fubject
with much attention; and I hope that my
efforts have not been altogether void of fuc-
cefs.   I proceed to exhibit fome fpecimens
chiefly from the order of fpathaceous cryf-
tals, and fhall then endeavour to explain
(as far as can be done upon a plane furface)
how the fpathaceous cryftals, fuitably ag-
glutinated together, may form the great
variety of diffimilar bodies which are to be
found among cryftals.

§ 11. *Various Figures derived from the fpathaceous Form.*

The calcareous fpar, as is well known,
confifts of a teffera, or oblique parallelopi-
ped;

ped ; all whofe planes are rhombi of fuch
a kind, that the obtufe angles are equal to
$101\frac{1}{2}°$, and the acute to $78\frac{1}{2}°$. Let us now
fee how, by a proper accumulation of fuch
fimilar parallelograms, cryftals of the moft
oppofite forms may be generated.

(A) Let A C E G O, fig. 1. tab. 1. repre-
fent a fpathaceous nucleus, through whofe
oppofite angles, D O, the axis H O paffes :
let us fuppofe, that contiguous rhombi are
applied to this, above and below ; and that
thefe rhombi are equal, fimilar, and parallel
to the fubjacent planes of the nucleus ;
thefe, to avoid confufion in the figure, we
fhall only reprefent by the rhombi M P, M Q,
and M T, which will be fufficient for thofe
who are fkilled in geometry and perfpec-
tive.

By this method an hexaedral prifm is
generated, confifting of fix equal and fimilar
parallelograms, and terminating at both ends
in three rhombi, which unite, and form a
folid angle : this form of cryftallization be-
longs to fome of the calcareous tribe, but
more particularly to fchoerls ; it is therefore
called the fchoerlaceous form.

(B) If the accumulation of the planes is
ftopped when the fides of the prifm have
acquired a rhomboidal nature, we fhall have
a dodecaedron included by rhombi : this is
the ufual form of garnet, when perfect.

(C) The garnetic form is eafily changed
into

into another, *viz.* into that in which the
hyacinth often prefents itfelf : this is ef-
fected by the regular application of equal
and fimilar rhombi to each of the folid an-
gles, which are compofed of four planes,
for the garnet has fix fuch, when complete
as to figure, and eight with three fides ; let
fig. 2. be confulted, where the dotted lines
exprefs the genefis of the prifm more intel-
ligibly than words can poffibly do. In this
operation the four rhombi are changed into
an equal number of oblong hexagons : L H
A B into L H h a b B, &c. &c. &c.

(D) Sometimes planes are applied, fimilar
indeed to the fundamental planes, but de-
creafing according to a certain law : this
decreafe, whether owing, as is moft proba-
ble, to a deficiency of matter, or to fome
other caufe, muft neceffarily change the ap-
pearance of the terminating planes, and oc-
cafionally either augment or diminifh their
number. Let us now return to fig. 1.—fup-
pofe fimilar planes, but continually decreaf-
ing (M p, M q, M t), applied to the internal
nucleus, thefe will ultimately end in an
apex on both fides ; fo that, inftead of a
prifm, we fhall have a double pyramid, one
tending upwards, the other downwards :
at the furface the planes which meet form
interfections or common bafes, whofe angles
alternately tend upwards and downwards, as
is fhewn by G F E A C B G : this is the form
of

of the calcareous cryſtals, which are called by the miners pig - tooth ſpars *(dentes ſuilli.)*

It is evident, that the axes of the pyramids are the longer, in proportion as the rhombi decreaſe more ſlowly ; and the contrary.

If the decreaſing ſeries is ſtopped before the ultimate ſides of the accumulated planes vaniſh, truncated apices will be generated ; of which frequent examples occur.

In the calcareous pyramidal cryſtal juſt deſcribed, if the dorſal margins A H, B H, or F H, be cautiouſly ſtruck, they break off into ſpathaceous teſſeræ ; but this is not the caſe with the alternate margins C H, E H, and G H, which it is ſcarce poſſible to bring to that ſtate ; the reaſon is evident — in the former caſe the direction of the blow is parallel to the accumulation of the planes ; whereas, in the latter, it meets the interſection of two planes :—this property alſo obtains in the lower pyramid, with this difference, however, which neceſſarily reſults from the very ſtructure, namely, that the margin A I muſt produce a directly oppoſite effect from the margin A H ; and the ſame is true of the reſt, *mutatis mutandis.*

(E) Frequently, alſo, the fundamental planes themſelves are imperfect ; if, in this caſe, planes ſimilar to them be added, forms of cryſtals muſt be generated more or leſs unlike the perfect form.—Examples of this

B 3   are

are very numerous; but in this place it will be fufficient briefly to explain a few.

Let A B C D E F G, fig. 3, reprefent the three rhombi which conftitute the apex of a perfect fchoerlaceous cryftal; let us now fuppofe the rhombus A G truncated in the direction of the line a b; c G along c d; and E G along e f. This being the cafe, the regular hexagonal figure of the prifm A B C D E F is changed to an irregular one, a b B C d D e f F, confifting of nine unequal fides, whofe apex is compofed of three irregular pentagons, a b B G F, c d D C B, and e f F G D. I have now in my poffeffion cryftals of this form, both calcareous and fchoerlaceous: to this clafs may be referred in general the rough turmalins, particularly thofe of Tyrol and Ceylon, of which we fhall fpeak more exprefsly (a) hereafter.

It is obvious that pentagonal periphery a b B G F approaches more nearly to triangular, in proportion as the diftance between a b and B F grows lefs; the fame is true of the reft: and when thefe diftances become evanefcent, a triagonal prifm is formed, terminated by three triangles: if the cutting line a b, c d, e f, approach ftill nearer to the center G, and equally, the form ftill remains the fame.

(F) The garnetic figure may be conceived as that of an hexaedral prifm, terminated at

(a) De Terra Turmalini.

each end by three rhombi, meeting at the apex ; and it may be compofed of four equal fpathaceous teſſeræ properly adapted ; I have already mentioned its geneſis (B) ; and its form is marked by the capital letters in fig. 4. If now, in the place of complete rhombi, we fuppofe accumulated in the fame manner about its axis others, whofe three external angles are truncated, or, which is the fame thing, if the longitudinal margins of the prifm be cut by planes parallel to the axis, a dodecaedron will arife, confifting of pentagons, which are indicated in fig. 4. by the fmall letters. Calcareous cryftals of this kind fometimes occur, but they are generally fo low, that e nearly coincides with a, c with d, &c. ; fo that the pentagon a b c d e becomes almoft of a triangular figure, which is the figure attributed to them by fome authors, who are ignorant of their true nature. Among the pyritacea we may fometimes obferve inftances of this variety complete.

Sometimes all the margins of the garnet are truncated, fo that the number of including fides increafes to twenty-four oblong hexagons ; a change which may eafily be derived from the pofitions already laid down. If the interfection c d, of the planes e c and c r, falls without the plane B G, a figure of a very different kind will be generated.

(G) The hyacinthine figure (art. c) also sometimes labours under defects peculiar to itself. I shall mention one very remarkable variety which is met with in Hartz mines (*b*): there the crystals sometimes appear of a cruciform figure (A B C D E F G H I K L M, fig. 5.); the apex is at c, the figure A B C b c a is all in the same inclined plane ; and that is the case with the other three homologous figures. Now, in order to investigate the primitive form, let the rhombi c N, c o, c P, and c Q be completed there, to an eye placed high in the axis, passing through c, will appear like squares situated in the subjacent plane, and we shall have the rudiments of this hyacinthine figure : for we may also conceive the granite form as a quadrangular prism, composed of four rhombi, touching one another only in their apices, and terminated at each end in four rhombi, meeting at the apex. This form, if a little protracted, or, what is the same thing, encreased by applying to the apices similar and equal planes, becomes the hyacinthine form, and therefore may without impropriety be denominated the rudiment of it.

(H) If the added planes be similar to one another, but not similar to the fundamental planes, prodigious varieties will arise from hence ; but I think it unnecessary at pre-

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(*b*) F. Ehrhart, that unwearied observer of nature, sent me some of these : they are siliceous, not calcareous, though they have the appearance of the latter.

fent to multiply examples, as what has been already faid, if well underftood, will be found abundantly fufficient to fhew how, by a plain and fimple method, many other figures may be reduced to the primitive forms.

(1) If any one imagines this doctrine to be purely geometrical and fpeculative, let him carefully examine the calcareous cryftals, the loofe texture of which, if cautioufly and fkilfully broken, will completely fhew the internal ftructure (c) : as to the harder cryftals, endowed with the forms above mentioned, their parts cohere fo ftrongly that they can fcarcely be broken : the fchoerls exhibit the fpathaceous texture very plainly; and there is no doubt, but the garnets themfelves are compofed of lamellæ, as will readily appear to an attentive eye.

(κ) Finally, we may add one peculiar obfervation concerning prifmatic and hexagonal calcareous cryftals, truncated perpendicularly; fuch fometimes occur, and they cannot derive their origin, in the manner above defcribed, from the fpathaceous particles, and by no other way can hexagonal prifms be generated : what then is the caufe which deftroys their apices ?—I confefs this to be a queftion which I am wholly unable

(c) My pupil, Dr. Gahn, firft obferved the central nucleus in pyramidal calcareous cryftals.

to

to anfwer, unlefs we may affume an accu-
mulation of planes, more and more defi-
cient around the axis.   We may from hence
conclude, that fomething unufual occurs, as
the truncated extremity is opaque, while
the reft of the prifm is tranfparent ; but the
upper hexagonal fection is fmooth and po-
lifhed.

(L) We have feen then prifms of three,
four, fix, or nine fides, occafionally termi-
nated by various apices : we have feen py-
ramidal, dodecaedral, cruciform, and other
very different figures, generated from the
fame fpathaceous form : befides, we fhall
obferve, that thefe almoft all occur, though
the nature of the fubftance remains the fame;
and from thence we fhould be induced to
put but little confidence in figure. If then
this teft, which undoubtedly is the moft
remarkable, fo far as externals reach, is of
fo little ufe, of what value can the others
be ?—and with what fuccefs can we hope to
form a fyftem of mineralogy upon fuch dif-
tinctions ? External criteria fhould certainly
not be neglected, but he who trufts impli-
citly to them deceives himfelf : they may,
to an experienced obferver, yield fome af-
fiftance, but can never ferve to determine
his affent.

§ III. *Structure of the moſt minute Parts.*

As ſo great a variety of forms may be produced by the ſpathaceous particles accumulated in different ways, it is probable that the differences of all cryſtals, with reſpect to externals, are owing to varieties in their mechanical elements. But here a queſtion may properly be ſtarted,—whether the moſt minute molecules, and as it were the ſtamina, are naturally poſſeſſed of a determinate angular figure, or whether they firſt acquire it during cryſtallization ?—In anſwer to this queſtion I beg leave to mention ſome circumſtances which occurred to me in the courſe of obſervation.

(A) If the ſmall particles which ſeparate from lime-water, when expoſed to the air, be inſpected with a microſcope, they will be found ſpathaceous.

(B) The greater ſpathous teſſeræ, when accurately examined, are frequently found with ſtriæ running diagonally (ſuch as we ſhall hereafter find appear in ſaline cryſtals) which diſcover their internal ſtructure.

(c) The cubes of common ſalt not only exhibit diagonal ſtriæ, but frequently, upon each ſide, they ſhew ſquares parallel to the external ſurface, and gradually decreaſing inwards (fig. 6) ; circumſtances which ſhew the veſtiges of their internal ſtructure :

for

for every cube is compofed of fix quadran-
gular hollow pyramids, joined by their
apices and external furface ; each of thefe
pyramids filled up others fimilar, but gra-
dually decreafing, completes the form. By
a due degree of evaporation it is no difficult
matter to obtain thefe pyramids feparate
and diftinct (as in fig. 7), or fix of fuch,
either hollow, or more or lefs folid, joined
together round a center ; this is the whole
courfe of the operation, from beginning to
end. All this is true of the falited vegetable
alkali, commonly called fal digeftivus fyl-
vii ; of the cryftallized luna cornea (*d*) ; of
the galena, or fulphurated lead, which is
frequently to be generated at Fahlun in the
heaps, roafted, as it is called *fub dio frigide* ;
quadrangular nitre too, which is of the fpa-
thous form, produces a fimilar congeries of
pyramids, and thefe almoft equally diftinct
with the preceding cubic cryftals. A folu-
tion of alum, upon evaporation, does ge-
nerally produce folid octaedra ; but fome-
times it alfo exhibits hollow pyramids, and
upon fuch of them as are complete the junc-
tures are very diftinctly marked by confpi-
cuous lines.

(D) Sometimes too other falts indicate
the fame conftruction by vifible diagonals.
The Rochelle falt forms an hexagonal
prifm ; a fection of which is fhewn by fig. 8 :

(*d*) C. H. Lommer, vom Hornertza.

when

when this kind of cryſtal is complete, the manner of arrangement among the internal particles is entirely unknown; but when the cryſtal is formed on the bottom of the veſ- fel, the lower ſide cannot be perfect (fig. 9); and this parallelogram exhibits two diago- nals diſtinctly (fig. 10.) This is alſo the caſe. with the ſalt extracted from human urine, which is called microcoſmic ſalt: beſides, we ſhould obſerve of the vertical triangles, that they are alternately tranſparent and opaque in pairs; which plainly points out a difference in the ſituation of their ele- ments. I have alſo ſome cryſtals of nitre marked with diagonals, a circumſtance which in others is generally concealed by the cloſe connection of the particles.

(E) If we examine the hollow pyramid of common ſalt farther, we ſhall find it compoſed of four triangles, and each of theſe formed of threads parallel to the baſe; which threads, upon accurate examination, are found to be nothing more than ſeries of ſmall cubes: therefore, although the above. circumſtances ſeem plainly to point out the geneſis of all cryſtals, from the union and coheſion of pyramids, whoſe ſides, being different in form and magnitude, occaſion the differences of forms; it yet remains un- certain whether the ſame internal ſtructure takes place in thoſe whoſe minuteneſs renders them totally inviſible; and whether the pri- mary ſtamina poſſeſs a determinate figure, or

are

are compofed by the union of many fhape-
lefs particles. We have long known that
the fmalleft concretions which are vifible
by the microfcope, poffefs a determined fi-
gure ;—but thefe are compounds : in the
mean time, until this veil is in fome meafure
at leaft removed, we cannot avoid comparing
the procefs of cryftallization with the con-
gelation of water.

While the watery particles are concreting
they exert a double tendency ; by one of
which they are formed into fpiculæ, by the
other thefe fpiculæ are ranged in fuch a
manner, with refpect to one another, as to
form angles of 60° : from hence the varie-
ties obferved in the particles of fnow may
be eafily explained. The moft fimple figure
is that where fix equal radii diverge from
a center, in the angle above-mentioned
(fig. 11.) (e) ; the fame angle will be pre-
ferved if the extremities of thefe be joined
by right lines ; which will alfo be the cafe,
if each of the triangles, thus formed, be
filled with right lines parallel to the bafe
fig. 12. I have alfo feen hexagonal figures
in fnow ;—but this by the bye.

Let us now fuppofe the particles which
are employed in cryftallization endowed
with a tendency to form fpiculæ, and thefe
fpiculæ with a tendency to arrange them-

(e) Mairan on Ice.

felves

felves at equal angles of inclination, and we
fhall have both the triangles and the pyra-
mids compofed of them, even although the
primary ftamina had not a determined fi-
gure ; as the angles of inclination vary, the
triangles and pyramids will alfo vary ; and
hence the different forms of cryftals will be
produced, which may to a certain degree be
inveftigated geometrically, the angles being
given.

   We have hitherto fuppofed the exiftence
of a double tendency, becaufe the effect
feems to be twofold ; but both thefe effects
may undoubtedly be owing to the fame
caufe, namely, to a mutual attraction be-
tween the particles, which, according to va-
rious fituations and peculiar figures of the
atoms, at one time arranges them in the form
of fpiculæ, again connects the fpiculæ already
formed under equal angles of inclination.—
I confider the mechanical elements as ex-
ifting under determinate and peculiar figures,
as, upon any other fuppofition, I find it im-
poffible to affign a caufe which fhould ar-
range different fubftances under different
angles, and yet preferve thefe angles always
conftant in the fame fubftance. But I do
not wifh to examine this conjecture any
further, though it appears to me to be pro-
bable ; becaufe powdered refin, which muft
doubtlefs confift of particles of a great va-
riety of forms, when fprinkled on an electro-
                                         phorus

5

phorus is, by the electric fluid, formed into stars like those of snow (*f*).

§ iv. *In how many different Ways Cryftals are generated.*

In order that the particles may be arranged, by the power of attraction, into determinate fymmetrical forms, it is neceffary that they fhould be at liberty, and very eafily moveable. The beft method of obtaining this end is to immerfe them in fome fluid of nearly the fame fpecific gravity with themfelves (*g*): this may be done in three different ways; 1. by water; 2. by a liquefying heat; 3. by a volatilizing heat.— Thefe we fhall confider in order.

(a) The moft common method of cryftallizing is by means of water, as it eafily takes up faline matters, and, upon being fufficiently diminifhed by evaporation, yields them again in a concrete ftate; nay, until now it has been thought, that without this vehicle no cryftals could be obtained.

But it is not only when actually diffolved in water that they require determinate forms; this, unlefs I am miftaken, is alfo the cafe when they are only fufficiently attenuated and mixed with it : for fubftances

(*f*) Lichtenberg firft obferved thefe refinous ftars.
(*g*) Morveau *Digreff. Academiques.*

not

not foluble in water will yet remain fuf-
pended in it, if by fufficient divifion they
have acquired fo great a furface, in propor-
tion to their mafs, as to approach the fpe-
cific gravity of the fluid : now fuch par-
ticles doubtlefs poffefs attraction, they alfo
poffefs the neceffary degree of mobility;
no reafon therefore appears why they may
not form cryftals. And it feems highly
probable that many of the earths which oc-
cur in the mineral kingdom fymmetrical
and of a regular form, have coalefced in this
way.

A mechanical mixture and a true folu-
tion fhould be carefully diftinguifhed, al-
though they agree in weight. In the for-
mer cafe the particles, if collected and laid
upon the bottom of the veffel, will remain
there, unlefs diffufed by agitation. A fub-
ftance which is foluble, on the contrary, is
totally and fpontaneoufly diftributed through
the menftruum, even without any agitation;
though the operation is certainly accele-
rated by agitation.

(B) Cryftals may frequently be obtained
by fufion and flow cooling : the matter of
heat, in fufficient quantity, penetrating folid
bodies which are not organic, foftens and
liquefies many of them; for when it pene-
trates and loofens the texture of the mafs,
it communicates mobility to each of them,
fo that upon flow refrigeration they are in a
condition to obey the laws of that attraction

which tends to arrange them in a regular manner : thus fulphur, when melted and cooled, exhibits ftriæ, and at the fame time acquires an electrical property : bifmuth, zinc, and regulus of antimony, acquire a fort of teffelated appearance ; nay, the laft of thefe, when fet to cool in a conical mold, becomes ftellated, not only on the upper furface or bafis of the mafs, but along the whole axis. Glafs, if melted and flowly cooled forms beautiful cryftals (*h*). I have taken the fcoriæ from furnaces where iron was fufed, by the addition of a calcareous ftone, and have fometimes found them of a regular prifmatic figure. When crude iron is melted with lime, I have found complete octaedra in the fcoriæ.

In large metallic maffes, fuch efpecially as are difficult of fufion, the lower particles are generally fo much preffed by the weight of the fuperior, that they fhew no figns of cryftallization, although on the upper furface of gold, filver, iron, and others, beautiful cryftals are formed.

It will perhaps be thought extraordinary, by thofe who have not well weighed the matter, that I fhould refer the congelation of water to an operation of this fort ; but we muft confider, that it is by means of the matter of heat that water is fluid (*i*) ; and

(*h*) Keir, Phil. Tranf. for 1776.
(*i*) Phlogifton, the matter of heat, and fire, ought to be carefully diftinguifhed : phlogifton, combined with pure
air

and that when this matter is diminished to a certain degree, it cryftallizes and becomes ice. We have before (§ 111. E.) compared congelation to cryftallization : in this place we fhall add another mark of refemblance.

Snow or ice, put into hot water, by its fo-lution abforbs a quantity of heat, equal to 72° of our thermometer : the cryftallized neutral falts produce the fame effect, that is, they make the water colder, although the falts and the water had been kept in the fame place for many days : for by diffolv-ing they acquire a larger furface, and by that means are able to take up and retain a portion of the matter of heat ; which, being fixed, lofes its power of heating, and confe-quently the thermometer finks when put into the water. Hence it follows, on the other hand, that the heat fhould be in-creafed during cryftallization ; and this in-crement is eafily obfervable when a large quantity concretes at once : in concreting the furface is diminifhed ; hence, fo great a quantity of the matter of heat cannot be re-tained : what is fuperfluous, being fet at liberty, recovers its property of heating, which it accordingly exerts, and that in proportion to its quantity.

air in a certain proportion, conftitutes the matter of heat : fire is the action by which a proper body is deprived of phlogifton, by means of pure air, with fuch vehemence as to generate not only heat, but flame.

(c) Heat not only liquefies but volati-
lizes certain bodies : the material cause of
heat penetrates the integrant parts, expands,
attenuates, and, by its union with them,
renders them so light, that they mount in
the air : particles, after undergoing this
procefs, when during cooling they are suf-
ficiently at liberty, often obey the laws of
attraction, and form cryftals : to this clafs
we may refer thofe which are condenfed
from the vapours of regulus of antimony,
called the flores argentini.   The galena,
which is frequently interfperfed among the
copper ore, at Fahlun, from the heaps which
are there roafted without heat, fends forth a
vapour which condenfes on the upper ftra-
ta, forming hollow pyramids, which form
the bafes of the cubes of galena, entirely
fimilar to thofe which compofe common
falt.

In the heaps of ore of arfenic which are
expofed to the fire at Loefa, I have collect-
ed extremely beautiful white, yellow, and
red cryftals, partly tetraedral, partly octa-
edral : fome of thefe exhibit hollow pyra-
mids, whofe fides confift of threads parallel
to the bafe, precifely in the fame manner as
the cryftals formed in the humid way (§ 111.
E.) ; fo that through the whole procefs of
cryftallization, a mechanifm every where
the fame, and analogous to cryftallization
feems to be employed : — nor let any one
imagine, that thefe are to be confidered as
                                    monftrous

monſtrous productions, which throw no light upon the theory of cryſtallization ; for theſe cryſtals, when complete, frequently ſhew the junctures of the pyramids, by very diſtinct lines ; and, by proper addreſs, we may be able to ſee the proceſs through its various ſteps, from the firſt rudiments to the completion of the whole operation.   If this ſtructure, as is very probable, takes place in all, yet it will not contradict what has been already ſaid concerning the ſpathous form, as elements of the ſpathous figure, properly applied, may readily form pyramids fit for this purpoſe.

A priſm of any kind may be formed by the apices of proper pyramids, meeting together in proper number round the ſame point ; and the apex may alſo be formed by a ſingle pyramid, its vertical angle being turned outward : thus a four-ſided priſm, with ſimilar apices, may ariſe in many ways : thus to the cube, indicated by the letters A B C D, fig. 15. let there be applied on each ſide the quadrangular pyramids A B E, and D C F ; and we ſhall have the priſm required.   In this way common ſalt ſometimes, though very ſeldom, acquires an apex (k).   Let us ſuppoſe applied to one or both apices of the octaedron A C B D, fig. 16. a hollow pyramid a d b, but ſimilar and equal to the fundamental figure ; and the ſame

(k) Capeler, *Prod. Cryſtallographiæ*, t. iii. fig. 2.

figure

figure will be produced : however, I muſt confeſs, that I have never ſeen alum priſmatic, though often conſiſting of octaedra imperfectly joined, fig. 17. A four-ſided pyramid may be compoſed of four tetraedra, and conſequently a cube of 24 ; and it has alſo a double apex of 32. Thus we have a new conſtruction, which undoubtedly ſometimes takes place ; for, as I have already ſaid, arſenical cryſtals take ſometimes the tetraedral, ſometimes the octaedral form, which may therefore eaſily be mutually changed.

It is with leſs facility that hexagonal priſms are formed of ſuch pyramids as have the ſame number of ſides, unleſs tetraedral be admitted. In fig. 18 four hexagonal pyramids and ſix tetragonal meet ; the firſt are eaſily reſolved into ſix, and the latter into four tetraedra (fig. 19.) ; forty-eight of which conſequently make up the whole maſs, ſuppoſing this to be the method followed by nature. I have no doubt that this conſtruction is probable, on many accounts, for it requires only the moſt ſimple elements, and ſuch as are conformable to the figures of all cryſtals. That tetraedra, adapted to this purpoſe, have ſometimes diſſimilar and unequal ſides, makes not againſt the ſuppoſition : but what is moſt to the purpoſe, is, that ſometimes ſuch tetraedra are employed without the ſmalleſt doubt. All theſe circumſtances are of no ſmall weight ;
but

but so long as no traces of tetraedra are to be found among the pyramids of common salt, the laws of sound reasoning forbid us to draw any general conclusion : it is better to pursue actual observations than fictions, however ingenious : better cautiously to examine the mysteries of nature, than hastily and presumptuously to decide.   I am perfectly certain that nature does frequently employ pyramids in this operation : it remains for future experiments to determine whether this be always the case, &c. I have been intent upon the mechanism of the concretion during a very assiduous examination of salts. I have related the principal phænomena which appeared, and at the same time have intersperſed various obſervations ; wiſhing that more sagacious obſervers may hereafter completely diſcover the system of corpuscular attraction, which is particularly obvious, and as it were palpable, in cryſtallization.

§ v. *Whether Cryſtallization neceſſarily implies the Preſence of a Salt.*

Some of the moderns, conſidering that many salts affect an angular form, and frequently one of a conſtant and permanent kind, ſuppoſed this property to belong excluſively to ſalts ; and when they met with any bodies ſimilarly figured, they attributed this figure to a ſalt which they ſuppoſed

concealed

concealed in that body :—what judgment we
are to form of this opinion, will appear
from the following confiderations.

(A) As cryftallization is the effect of at-
traction ; and as all other matters, as well as
falts, are fubject to the laws of that attrac-
tion, we are not authorized to confider the
regular and fymmetrical figure as peculiar
to faline bodies, although the affumption of
fuch figure be more readily and frequently
exercifed by them, as being foluble in water.
But cryftals are produced by fuch other me-
thods as can fufficiently divide and difen-
gage the integrant parts (§ IV. B and C.)

(B) Upon examining falts it will plainly
appear, that thofe which are moft fimple,
and poffefs the faline properties in the moft
eminent degree, coalefce with the greateft
difficulty. The truth of this affertion is
evinced by the mineral acids and the cauftic
alkali, which, when pure, and freed as much
as poffible from every heterogeneous matter,
it is fcarce poffible to reduce to the form of
cryftals.

(C) The fimilarity of forms in cryftals
does not depend upon the acid ; for, to pafs
over many other examples, the prifmatic
and quadrangular nitre, which are formed
by the fame acid, yet conftantly differ in
figure :—neither is the bafe fufficient ; for
the vegetable alkali, as well as the mineral,
faturated with marine acid, generates cubic
cryftals. The external appearance there-
fore

fore depends upon the menftruum and the bafe jointly:—we are not, however, from thence to conclude that there is prefent a neutral or middle falt, whenever the figure of fuch a one is difcoverable. Not the fmalleft particle of alum is found in lead or nickel united with nitrous acid, although both thefe compounds yield octaëdral cryftals.

(D) A great variety is obferved in cryftals, though the matter remains the fame: I have already fhewn this to be the cafe with calcareous cryftals (§ 11). In the family of the pyrites, cubes are fometimes found ftriated in a fingular manner, fo that the lines of one fide are perpendicular to thofe which diftinguifh the four adjacent fides (fig 13); but among thefe are alfo found tetraedra, octaedra, dodecaedra, and icofaedra; fo that in this cafe all the regular folids are found.

(E) Finally, a very great number of cryftals are either totally deftitute of any thing faline, or elfe poffefs it in fuch fmall quantity that no experiments hitherto tried have been able to difcover the fmalleft fenfible traces of it. I have in my poffeffion hexangular prifms of mica, which are compofed of parallel lamellæ; the elementary fpiculæ of which are difpofed in a fingular manner (fig. 14): gems, granites, fchoerls, and other earthy bodies, are frequently found figured, though analyfis can difcover nothing faline. The fame is true of gold, filver, and the other native metals; as alfo gold, filver, lead,

lead, tin, bifmuth, and zinc, united with mercury, of which all put on regular forms, according to the quantity of the mercury (*l*).

If we have recourfe to the fuppofition of an hidden faline fubftance, which cannot be difcovered by art, it will furely be unreafonable to attribute to fuch a principle fo great a power as that of arranging the particles in the order neceffary for cryftallization ; a caufe beyond queftion unequal to the magnitude of the effect : for how is it poffible that a faline matter, the prefence of the fmalleft atom of which cannot be difcovered by the moft delicate tefts, fhall in pure water have yet power to effect the icy cryftallization with fuch force as to overcome the moft powerful obftacles ? How can a faline matter, which by no teft can be difcovered, have power, in an amalgam of gold, to arrange the ponderous particles of both metals in a particular manner ? What falt is able to form the ftellated regulus of antimony ? what the hexagonal lamellæ of mica ?—Thefe obfervations will fuffice for thofe who wifh to build their knowledge upon the folid bafis of experiment— to thofe who indulge hypothefes, the experience of centuries will convey neither conviction nor information.

(*l*) *Mem. de Chémie*, par M. Sage.

DISSERTATION XIII.

OF

SILICEOUS EARTH.

———————

§ 1.

WE find it long fince obferved by Theophraftus the Erefian (*a*), that a moft excellent glafs might be formed of that fpecies of ftone which ftrikes fire with fteel, and is called flint ; and hence perhaps it was, that all ftones which joined to alkaline falts can form a glafs, were called vitrefcible. There are fome, indeed, who explain this denomination in another way, and confider it as indicating only the property of melting by means of fire without

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(*a*) De Lapid. 84. So Pliny, " *Auctores funt, in India & cryftallo fracto fieri (vitrum) & ob id nullum comparari Indico.*

addition.

addition. But as vitrefcible earths, when alone, are very refractory, the former account feems to be more probable.

In the prefent century thofe ftones which had before been called vitrefcible, were called filiceous by Mr. Pott, and after him by Mr. Cronftadt. The celebrated chemift of Berlin, above-mentioned, feems to have been the firft who (in 1746) eftablifhed the genuine criteria of thefe ftones; at leaft he determined them more accurately than any perfon before his time, and, after aftonifhing labour, difcovered their habits, in mixture with the various earths and falts (b). Stones which are fo hard as to ftrike fire, are commonly called filiceous; but this property depends more upon the connection of the particles than the nature of matter itfelf.

Glauber (c), if I miftake not, was the firft who gave a clear defcription of the liquor of flints; though J. B. Van Helmont, in fpeaking of glafs, afferts that if it be made with too much alkali it deliquefces; and that, by means of an acid, it precipitates a quantity of filiceous earth equal to that which had been ufed in the making of the glafs (d).

Siliceous earths have been but little examined with regard to their principles and compofition. Geoffroy afferts, that by repeated calcination they may be refolved into abforbent earth (e). Neuman relates, that

(b) Gethogeogn.   (c) Furn. pars 2.
(d) De Terra.   (e) Mem. Par. 1764.

he

he obtained from them, by diftillation, an oily empyreumatic fubftance, which made fyrup of violets red, and, upon addition of concentrated vitriolic acid, diffufed the fmell of volatile fpirit of falt (*f*) : but Ludovici, upon diftillation, obtained, as he relates, from a pound of filiceous earth, two drachms of an acid liquor with a fulphureous odour, and the refiduum by elixation communicated a ftyptic tafte to water, from which, by alkali of tartar, a tartar was precipitated (*g*). Carl alfo obtained an acid liquor of the fame kind (*h*).

Others fay that they have obtained it fublimed with fal ammoniac, of a variegated colour, together with a green liquor. Neuman (*i*) afferts, that he was able, by means of vegetable acids, to extract a portion of lime from mountain cryftal, but not from quartz ; that the acids acted more powerfully upon the cryftals when calcined ; that of one drachm of the fofter flint 22 grains were diffolved by concentrated vitriolic acid, and by the diluted acid 20 ; by marine acid 15 ; by nitrous acid 16 ; by vinegar 10 ; but that from the harder flints which ftrike fire, nothing was extracted (*k*).

Glauber (*l*) imagines, that on diftilling powdered quartz or flint with two or three

(*f*) Prælect. Chem.
(*g*) Eph. N. C. Dec. an. 6 & 7.
(*h*) Juncker Confp. Chem. t. i.
(*i*) L. c.   (*k*) L. c,   (*l*) L. c.

parts of alkali of tartar, it foams out of the retort, and diffufes an acid liquor like to marine acid in fmell, but differing from it in tafte, and other properties; this liquor he thinks is derived from the alkaline falt, though Stahl afcribes it to the filiceous matter.

Pott afferts, that the earth precipitated from liquor of flints (*m*) by acids, is perfectly foluble in them, and that with vitriolic acid it produces alum (*n*); this was afterwards affented to by Beaume (*o*), but is very juftly denied by Cartheufer (*p*), Scheele (*q*), and others (*r*). The celebrated J. C. F. Meyer obferved (*s*), that liquor of flints, dilated with a certain quantity of water, bore acids without precipitation: this is a remarkable phænomenon, which will be explained hereafter.

Finally, the celebrated Dr. Prieftly, who is making attempts to refolve all bodies into air, having expofed filiceous powder, moiftened with acid of nitre, to an intenfe heat, obtained, in an apparatus prepared for the purpofe, firft aerial acid, then nitrous air and common air, and laftly air of remarkable purity; and thefe he obtained in the

(*m*) Contra Ellerum.
(*n*) Lithog. p. 3. præf.
(*o*) Man. de Chémie.
(*p*) Miner. abh. theil.
(*q*) Act Stock. 1776.
(*r*) Diff. couronnée par la Soc. Montp.
(*s*) Befchaft. der Berl. Gefellfch.

fame

fame order feveral times, by moiftening the mafs afrefh (*t*).

The illuftrious Count de Buffon confiders clay as flint minutely divided, and on the contrary flint as clay very much condenf-ed; how juftly, will appear from the fe-quel. We fhall pafs over the loofe conjec-tures of authors concerning the origin of this earth; conjectures which are only built upon the places where it is found, its fitu-ation, or other circumftances often very trifling; and only obferve, that pure fili-ceous earth is generated in the diftillation of the mineral fluor with vitriolic acid; a fub-ject which has been fo ably handled by Mr. Scheele. How this genefis of filiceous earth is effected we fhall enquire hereafter in its proper place.

§ 11. *Criteria of Siliceous Earth.*

In order to avoid all future ambiguity, it is neceffary to begin by defining what is underftood by the term *filiceous earth.* It is that earth which is precipitated by acids from liquor of flints, and which, even though the acid be fuperabundant, remains undiffolved. Clay is alfo diffolved by alka-line falts, and is alfo precipitated by acids; but is again taken up by the acid, if fuffi-cient quantity be added. I fhall therefore

(*t*) Experiments on Air.

pass over the latter, and go on to mention some of the principal properties of the former earth, such as are often useful to distinguish it from others; but I shall only take notice of a few properties which may serve as criteria. The following are the most remarkable, and such as serve to distinguish it very easily from all others.

The siliceous earth is not acted upon in the usual way by any acid, that of the mineral fluor excepted.

But it may be dissolved in fixed alkalis, either by the dry or the humid way; and in the former case, with violent effervescence, runs into a glass which is so much the harder as the siliceous earth, by means of a due degree of heat, constitutes a larger proportion of the whole mass. With $\frac{1}{2}$ alkali a clear and very hard glass is obtained; but with double or triple the quantity, a vitrified mass, which attracting the moisture of the atmosphere, deliquesces spontaneously.

It cannot be fused when alone by the most violent ordinary fire, but is dissolved by the addition of borax, without effervescence; it is also taken up by the microcosmic salts, though far more slowly and sparingly.

§ III. *Its Habits with Acids.*

The earth newly precipitated from liquor of flints, when washed and still wet, cannot be dissolved in the common acids, such as vitriolic

vitriolic, nitrous, and marine, although in that ftate its furface is increafed as much as poffible; and although to each part of earth 1,000 of concentrated acid were added, and boiled for an hour, the filiceous mafs, when afterwards collected and wafhed, remains of the fame bulk as before, and the menftruum is not impregnated with the fmalleft particle.

This is ftrictly the cafe with regard to pure filiceous earth; but if three parts of alkaline falt be melted in a common crucible with one of quartz, the falt diffolves at the fame time about 0,07 its own weight of the argillaceous matter of the veffel, which are precipitated by acids, and re-diffolved upon adding a fufficient quantity of the acid menftruum: but it is obvious that in this cafe the argillaceous clay is a foreign admixture, and by no means a conftituent part of the liquor of flints. If the operation be performed in an iron veffel there will be no argillaceous earth obtained, however often the experiment be repeated. There is certainly a portion of clay, though extremely fmall, which is always found in quartz itfelf: but the filiceous earth precipitated from liquor of flints, and freed by an acid from all heterogeneous matter, though afterwards repeatedly fufed with fixed alkali in an iron veffel, will not yield even the moft minute portion of clay; thefe different cafes fhould be well obferved, left we be led into an erro-

neous belief of the converfion of filiceous into argillaceous earth.

We fhall hereafter (§ iv. c) fee that fili-ceous earth may, by certain management, be diffolved in acids.

(b) The fluor acid is never got entirely free from filiceous earth; fo that, being more or lefs loaded with it, it muft of courfe be found lefs active. Here it is proper to obferve, that fuch earth is called filiceous as is either collected in the recipient during the dif-tillation of fluor acid, or is afterwards de-pofited by that acid: the reafon of this de-nomination will appear hereafter (§ v).

In order to examine the folvent power of this acid, in the year 1772 fome quartz very finely powdered was put into a bottle which contained $\frac{1}{8}$ of a kanne of the acid; the bottle was then flightly corked, and fet by in a corner of the room; two years afterwards it was examined, and, the liquor having been poured out, there were found concreted at the bottom of the veffel (befides innumer-able fmall prifmatic fpiculæ) thirteen cryf-tals, of the fize of fmall peas, but moftly of an irregular form; fome of them refembled cubes whofe angles were all truncated, fuch as are often found in cavities of flints. Thefe filiceous cryftals, the firft perhaps that were ever produced by art, were indeed hard, but not comparable with quartz, except in effen-tial properties, in which they perfectly a-greed. Poffibly the length of a century may
· be

be neceſſary for them to acquire by exſicca-
tion a ſufficient degree of hardneſs. The bot-
tle itſelf, as far as the liquid had reached,
was found covered on the inſide with a very
thin ſiliceous pellicle, which was ſcarcely
viſible, but ſeparated on breaking the bot-
tle; it was extremely pellucid, flexible, and
exhibited the priſmatic colours.

These phænomena ſhew that much ſili-
ceous matter is diſſolved and ſuſpended: whe-
ther any of the quartz was taken up is uncer-
tain, but it appears probable that little or
none was diſſolved in this experiment, ſince,
by the help of heat, during the diſtillation the
acid had previouſly taken up ſo much ſili-
ceous earth, that upon ſlow evaporation it
was unable to retain it: hence appears the
origin of the cryſtals and the pellicle; and
hence appears the cauſe which impedes the
action of fluor acid upon flint; namely, that
the acid obtained in the ordinary way is al-
ready ſaturated with it.

Flint diſſolved in fluor acid is moſt com-
pletely precipitated by volatile alkali; and
by this method it is found that one part of
flint is contained in 600 of the acid ſo
much diluted that its ſpecific gravity is
only 1,064. This precipitate poſſeſſes all
the criteria of pure flint (§ 11.): but that
which is precipitated by fixed alkali, either
vegetable or mineral, does not exhibit a pure
ſiliceous matter, but a triple ſalt of a pecu-
liar kind, compoſed of ſiliceous earth, fluor

acid,

acid, and fixed alkali, which diffolves, tho'
difficultly, in warm water (efpecially that
which is made with vegetable alkali), but is
eafily decompofed by lime-water, and lets
fall the mineral fluor regenerated; fo that
this precipitate muft be well diftinguifhed,
and not confounded with that which is pre-
cipitated by volatile alkali.

§ IV. *Its Habits with alkaline Salts.*

In the humid way (by boiling) fixed al-
kaline falts attack the filiceous earth, but
not unlefs it be very finely comminuted, and
newly precipitated from liquor of flints.
Alkali of tartar, fpontaneoufly diffolved by
attracting moifture from the atmofphere,
by boiling takes up about one-fixth of its
own weight ; and the liquor, upon cooling,
forms a jelly, although at firft diluted with
fixteen times its weight of water. This
folution is effected by the cauftic portion
which is always prefent in this alkali, for
when the alkali is aerated it rejects the
earth ; nay, upon the addition of aerial acid,
even the cauftic alkali depofits the earth.

The volatile alkali, even though cauftic,
has no effect in this way.

(B) In the dry way fixed alkalis attract
filiceous earth, infomuch that one-half its
weight of thefe falts melt with it into a
glafs tranfparent, hard, and firm ; which is
not

not the cafe with any other earth yet known. During the conjunction a violent effervefcence is obferved ; but if the vapour which afcends be collected, it is found to confift of nothing but water and aerial acid.

If the proportion of alkali be greater, a glafs is obtained more foft and lax ; and if it be increafed to double or triple, the glafs attracts the moifture of the air, and is refolved into a liquor, which (from the filiceous earth) is called liquor of flints.

(c) This liquor is precipitated by all acids, as the alkali unites to them more readily than to the filiceous earth, which (being thus deprived of its menftruum) falls to the bottom. The filiceous matter, thus precipitated, is of an exceeding loofe and fpongy texture, and is fwelled by water fo much that its bulk when wet exceeds its bulk when dry at leaft twelve times : nor does it contract more in the water, though fuffered to reft in it a long time. Hence the liquor of flints may, by time and a quantity of precipitant properly adjufted, be eafily converted into a jelly, efpecially if diluted with four or eight times its weight of water : for in that cafe the fluidity is fo regulated that the precipitant can eafily feparate the filiceous particles, and the particles fo feparated can at once occupy the whole mafs ; but if an overproportion of water be ufed (for inftance, twenty-four times the weight) in this cafe the liquor remains limpid, al-

D 3   though

though fo much acid be added as is more than fufficient to faturate the alkali. This is a remarkable phænomenon, the rationale of which, if I miftake not, is the following : —

The filiceous particles are removed from each other very much by the diluting water; or rather, being diffufed through fo large a mafs, are more rare. Now by every diminution of bulk the furface is encreafed, and, together with that, the contact of the furrounding fluid; hence, although the filiceous earth, by its fpecific gravity, fhould fall to the bottom, yet in the prefent cafe it is not able to overcome the refiftance occafioned by friction, for greater force is requifite to open the way downwards than is fupplied by the difference of fpecific gravities: the filiceous molecules therefore remain fufpended in the fluid at the fame time invifible, both on account of their tenuity and their tranfparency : but if the bulk of the fluid be diminifhed by evaporation, efpecially by boiling, which at once diminifhes its gravity and tenacity, the filiceous matter is feparated.

Liquor of flints is alfo decompofed by too great a quantity of water; for by this the efficacy of the alkaline menftruum is fo much diminifhed, that it is no longer able to keep the filiceous matter diffolved, and it is alfo partly faturated with the aerial acid inherent in the water.

(D) It

(D) It may seem extraordinary, that fluor acid should precipitate liquor of flints, as this acid strongly attracts the siliceous earth; but it is to be observed, that it still more strongly attracts the alkali: besides, in this case, it is not a pure siliceous matter which is precipitated, but an earth, combined both with acid and alkali, as was before observed (§ 111. B). But there is some difference in the two cases, for in this instance the acid and the alkali, both loaded with siliceous earth, meet one another: while, therefore, the acid is saturated with alkali, it alone deposits a quantity of siliceous matter, this deposition therefore may all be dissolved by moderate heat in a sufficient quantity of water; and when exposed to the flame by a blow-pipe, readily fuses, exhibiting a pellucid little sphere, which, upon losing its fluidity, grows opaque and white. The precipitate from liquor of flints by fluor acid has the same properties, but somewhat less solubility and disposition to liquefy, doubtless occasioned by a larger proportion of siliceous earth: both these saline precipitates contain the fluor acid, which is discharged upon the addition of the vitriolic, and the ordinary phænomena exhibited. To an inattentive observer it will appear, that in this case we have the fluor mineral accompanying the acid; but a more accurate examination will detect this error: for the residuum, after the distillation of fluor, always contains gypsum, some-

times

times mixed with alum and flint, whereas here nothing remains but vitriolated alkali, intermixed with flint. Hence we see how much caution and vigilance is neceſſary to prevent us from embracing error inſtead of truth.

(E) The aerial, which is the weakeſt of all acids, yet precipitates liquor of flints ; and that quickly and copiouſly, if it be ſuddenly added, and in ſufficient quantity ; but it is not neceſſary to mix them, it is ſufficient if liquor of flints be expoſed to the atmoſphere, either open or imperfectly ſhut, for then the ſubtile precipitant is attracted, and the fluid depoſited very ſlowly, in proportion as the alkali is aerated.

§ v.   *Siliceous Earth poſſeſſes ſomewhat of a ſaline Nature.*

The proof of this is not to be drawn from the cryſtalline figures which ſiliceous ſtones often aſſume (for this is a property not peculiar to ſalts) more convincing arguments may be drawn from its compoſition and its ſolubility.

(A) In order to underſtand the geneſis of ſiliceous earth, as far as it has yet been poſſible to penetrate that myſtery, let us attentively conſider the diſtillation of fluor acid : the phænomena of this operation are entirely of a new ſpecies, and, to be well underſtood, require the greateſt ſkill and attention.

Let

Let 100 parts of pulverized fluor be put into a glafs retort, and through a tube 50 parts of highly concentrated vitriolic acid be poured in; immediately a fenfible degree of heat is found to arife in the mafs, and a vapour of a moft penetrating odour is produced; let 100 parts of diftilled water be kept in the recipient; let a gentle heat be applied, which is to be raifed by degrees, until the bottom of the retort becomes at laft red: during this time the body and neck of the retort are incrufted by a white matter, and the furface of the water in the recipient is covered with a cruft of the fame colour. When the veffels cool let the white matter in the recipient be firft collected, well wafhed and dried; — it is found to be equal to about one part and a half of the mafs fubjected to the diftillation.

This is very light and fpongy; not only infoluble in water, but in the ftrongeft acids; very refractory in the fire when alone; with one half of fixed alkali it yields a tranfparent and ftrong glafs, but with three times that quantity produces a faline mafs, which deliquefces, and becomes liquor of flints: in a word, it exhibits all the criteria of a true and pure filiceous earth; and, on expofition to the focus of a burning mirror, agrees with that earth, as the celebrated Macquer experienced with a fmall portion of this filiceous powder, artificially prepared in the laboratory at Upfal.

7   Befides

Besides the siliceous earth above mentioned, which is chiefly formed in the recipient, a white pellicle adheres to the neck and body of the retort ; this, upon examination, is found to be nothing but the mineral fluor, more or less deprived of phlogiston, enveloped even externally by its own acid, but containing little or nothing of siliceous earth : it therefore easily fuses, upon exposure to the blow-pipe, and, upon addition of vitriolic, the fluor acid is expelled.

If the distillation be performed with an equal, a double, or a still greater quantity of vitriolic acid, the same phænomena take place, but with greater vehemence ; more of the fluor is volatilized ; and it sometimes even passes over into the receiver : the glass is almost always corroded, and, if thin, perforated. The water in the receiver, which by the first method contains a pure fluor acid, is in the latter more or less mixed with the vitriolic. The elastic fluid, which is generated, and may be collected in mercury, does not proceed entirely from the fluor alone, but is also mixed, more or less, with something proceeding from phlogisticated vitriolic acid ; so that a wrong judgment is formed of the whole elastic fluid, from that by which it is adulterated.

The mineral fluor, distilled in the same manner with four times its quantity of nitrous or marine acid, yields the same product ;

duct; but a smaller quantity of fluor is vo-
latilized, less fluor acid is extricated, and less
siliceous earth is produced : the water in
the recipient, besides the fluor acid, always
contains somewhat of the decomposing acid ;
nay, the acids of the vegetable and animal
kingdoms produce the same effect, but in a
smaller degree.   The siliceous earth is then
generally found to be wanting in the re-
ceiver ; and from the weakness of the de-
composing acid a smaller quantity of fluor
acid is expelled, sometimes indeed so small,
that the whole of the earth produced is dif-
solved, but it can again be separated by vo-
latile alkali.   According to the new table
of attractions of the fluor acid it has a greater
affinity with lime than the nitrous, marine,
and other acids have ; and this is agreeable
to experience ; but when heat is applied the
more volatile, though it be the stronger acid,
must yield to the more fixed : the fluor obsti-
nately resists fire when alone, but by means
of another acid a small degree of heat is suf-
ficient to volatilize it.   The mineral fluor,
though often heated and extinguished in
water, yet, when afterwards distilled with
vitriolic acid, yields its acid in the usual
way.

Most of these phænomena are easily un-
derstood, upon the supposition that the fluor
acid, united with lime, constitutes the fluor
itself ; that it is very volatile ; and that
when expelled it elevates some of the fluor
                                                        to

to a certain height; and that this height is
the greater in proportion as the expulsion of
the acid is quicker. It has also been demon-
strated before (§ 111.) that when hot it
attracts siliceous earth very powerfully; and
this without doubt is the reason why glass,
which is always partly composed of siliceous
earth, is corroded.

The principal objections which in this
business obscure the truth, and diminish the
validity of our conclusions, though already
mentioned, shall here be set in view toge-
ther, as they throw several obstacles in the
way of our research. These are, 1st, the im-
moderate quantity of vitriolic acid: if the
fluor acid only be required, one-half the
weight of the decomposing acid is sufficient;
if a perfect decomposition of the fluor, there
is need of four times the quantity, and in
general we cannot err by the largeness of
the proportion. 2d, By want of water in
the receiver the glass vessels are more corrod-
ed, and the elastic vapour, which cannot be
condensed into a liquid form without it,
now for the most part bursts forth, being
only confined by the portion of water which
adheres to the vitriolic acid. Great obscu-
rity arises from, 3d, confounding things that
ought to be distinguished from each other:
the volatilized fluor, the pure siliceous earth
found chiefly in the receiver, the precipi-
tates from the fluor acid by fixed or volatile
alkali, are all substances that should be care-
fully

fully distinguished. In like manner the elastic fluid, elicited from the mineral fluor by a proper quantity of vitriolic acid, is very different from that obtained by the same acid phlogisticated.—But let us return to our proper business, for all the properties of fluor acid do not belong to the present enquiry, which only regards the siliceous earth. I thought it however necessary to mention such of them as lead directly to the end proposed.

The question then is, whence the siliceous earth which occurs in the operation is derived? whether it is extracted from the mineral fluor, and elevated by the fluor acid, or whether it is extricated from the glass vessel itself?—many circumstances, hereafter to be mentioned, are repugnant to each of these opinions; and the experiments which have hitherto been instituted rather seem to indicate that this substance is actually produced during the operation.

1st. That the siliceous earth does not owe its origin to the mineral fluor is easily shewn: for although this fluor sometimes contains siliceous earth, yet this does not always happen; and nevertheless as large a produce of that earth is had from that which is entirely destitute of siliceous matter as from that which contains it. The green earth of Garpenberg, for instance, is in general entirely free from siliceous earth, and therefore may be totally dissolved, either in

nitrous

nitrous or marine acid. This folution, upon the addition of cauftic alkali, precipitates pure fluor, totally unchanged ; but the mild alkali, by means of a double elective attraction, precipitates aerated lime : — on the addition of vitriolic acid gypfum is formed.

2d, As the glafs is corroded by the vapour of the fluor acid, at firft fight it appears not an improbable conjecture, that the filiceous earth which appears is produced from thence ; but we muft obferve, that by employing a fmall quantity of fluor and a gentle fire, the filiceous earth may be obtained without any corrofion ; befides, the corrofion bears no proportion to the quantity of filiceous earth.

3d, That the filiceous earth, diffolved or volatilized by the acid, paffes over from the retort into the receiver, is an opinion contradicted by a variety of experiments ;—if, in place of water, alcohol be put into the receiver, the acid is collected in it, but no filiceous powder, which, on the hypothefis of volatilization, ought to be found. Of this circumftance we fhall fpeak more at large hereafter.

But the powder formed in the receiver, well wafhed, and diftilled with vitriolic acid, is not elevated, much lefs does it pafs over into the receiver, and it yields no fluor acid. Left it fhould be fufpected that this is owing to a deficiency of the phlogifton neceffary

to

to volatilization, let a few drops of olive
oil be added, and from hence, upon the ap-
plication of heat, a white fmoke will arife;
and if the end of the retort's neck be plung-
ed in water, a white fquamous membrane
is generated on the furface. This would at
firft appear a proof of the volatilization of
filiceous earth, but upon examination the
error is difcovered; this membrane being
found to be nothing more than a febaceous
matter difcharged from the oil by means of
the acid, in a ftate of coagulation, and car-
ried up by the fmoke; and the fame kind
of membrane is produced, if nothing be ufed
but the oil and the acid. If the fluor acid
be nothing more than a modification of the
vitriolic (a queftion which muft be decided
by future experiments) the change produced
in this cafe is a very fingular one, and muft
be totally different from that occafioned in
general by phlogifton: in the mean time it
cannot with juftice be denied, that the fluor
acid is contained in the fluor itfelf; for if
the fluor acid be mixed with lime-water, the
mixture immediately becomes turbid, and a
powder is depofited, which, wafhed and dried
in a certain degree of heat, becomes phofpho-
ric; diftilled with vitriolic acid it yields fluor
acid and filiceous earth, and agrees in all re-
fpects with the mineral fluor. On what pre-
text then can it be denied that the acid which
was juft now mixed with it is prefent in it?
The mineral fluor is therefore lime faturated
with

with fluor acid. Sometimes, indeed, there
is prefent a little clay and flint; thefe, how-
ever, are not always found, but only cafually,
and they by no means conftitute the effence
of the fubftance. The greateft quantity that
I have yet found was four grains of clay in
an ounce of mineral fluor, that is $\frac{1}{120}$. There
is alfo fometimes a fmall portion of marine
acid, which has not yet been found to exceed
five grains in an ounce of mineral fluor.

Upon confidering thefe circumftances,
which are not the refult of a fingle experi-
ment flightly confidered, but of diftillations
frequently repeated and accurately examin-
ed, it feems neceffary to have recourfe to a
new production, a thing which indeed
fhould never be attempted but upon the beft
grounds.

In general we can no other way con-
ceive the nature of fluid bodies than by
confidering them as congeries of folid
particles, which are fo minute that when
combined with a certain quantity of heat,
they acquire that degree of mobility which
is fufficient to preferve a level furface;
which level, if by any means difturbed, is
immediately recovered. Now the primary
aqueous elements, united while in a fluid
ftate with fluor acid, fcarcely contract a firm
texture, but yield a dilute acid, a circum-
ftance which takes place with refpect to other
acids; but upon the application of heat they
put on the form of an elaftic vapour, and

in

in this ftate meeting with the vapour of the
fluor acid, it is extremely probable that by
their union they form the white powder
above-mentioned : it is certain that when
liquid they both offer a much fmaller furface
of contact than when in the ftate of vapour;
and this difference in the latter cafe occa-
fions a very clofe union, which in the for-
mer can fcarce poffibly take place, on ac-
count of the fmall furface of contact.—If
mineral fluor be treated with highly con-
centrated vitriolic acid, unlefs there be wa-
ter in the receiver, the elaftic vapour can
fcarcely be condenfed into a liquid form, but
for the moft part penetrates the luting, and
corrodes the glafs in a more than ordinary
manner : by means of the water, which ftill
adheres to the vitriolic acid, a fmall quantity
of liquor will be formed; *viz.* as much as
efcapes being condenfed into an earth. The
acid vapour itfelf, collected in mercury, yields
an elaftic fluid not condenfible by cold; wa-
ter abforbs this acid fluid, but watery va-
pour coagulates it. Hence we may under-
ftand why pulverized mineral fluor, when
expofed to a digefting heat in a clofe cu-
curbit, with twice its quantity of con-
centrated vitriolic acid, covers wet bodies,
fufpended over the mafs, with a white pow-
der, while dry bodies expofed in the fame
way do not contract a particle of powder;
as alfo, why the fluor acid, often diftilled
with water, may be totally converted into

VOL. II.   E   filiceous

filiceous earth. There is therefore neceffary
for this concretion (befides the hot acid va-
pours) water, alfo converted into vapour;
and the coagulation is performed with great
difficulty within the mafs, but very eafily
at the furface, which, while fluid, is in a
perpetual ftate of evaporation.

But whatever be the caufe of this fingular
union (which is highly deferving of accu-
rate examination) it is at leaft certain that
the fluor acid makes a part of it: fuch a
combination is very analogous to the neutral
and middle falts, and therefore is not with-
out reafon confidered as partaking of a faline
nature, although fcarcely foluble in water,
in the fame manner as gypfum, or as the
mineral fluor (which confifts of fluor acid
faturated with lime, and is totally infoluble
in water) is acknowledged to approach to
the nature of middle earthy falts.

(B) Let us now fee whether filiceous
earth be totally infoluble in water. That
certain waters contain filiceous earth is be-
yond a doubt; but it is probable that it ra-
ther remains fufpended in them by means
of the fubtlety of its parts, than in virtue
of a true folution.

It is known that water becomes the more
capable of diffolving bodies, in proportion
to its degree of heat; but in open veffels it is
incapable of receiving a degree of heat greater
than that of the boiling point, or 100°. Si-
liceous earth, expofed in water to a boil-
ing

ing heat for ever so great a length of
time, is scarce sensibly diminished, so that
by this experiment it seems totally inso-
luble; but we cannot thence conclude
that it is able to resist a greater heat. The
efficacy of Papin's digester has shewn, that
many bodies may be dissolved which totally
resist boiling in open vessels: at the same
time it must be confessed, that no one has yet
tried siliceous earth in this way; so that we
should be entirely ignorant what would be
the event, had not nature herself sponta-
neously assisted our ignorance and sloth.

Thus, at Geyser in Iceland there springs
up a hot water, which upon cooling de-
posits siliceous earth, and of this very
matter has formed for itself a crater, in
which columns of water of a stupendous
bulk, after they have been thrown to the
height of 90 feet and upwards, fall, and
are again received. The heat of the water
during the explosion cannot indeed be mea-
sured; but after it has risen and fallen
through a stratum of air 90 feet thick, it
raises the thermometer to 100°; which evi-
dently shews that the heat in the bowels of
the earth must be vastly more intense; and
this we shall cease to wonder at, when we
consider that in this case the subterraneous
fire acts upon the water in caverns closed
up by very thick strata of stones, an appa-
ratus far more effective than Papin's digester.
The crater undoubtedly was at first formed,

E 2 and

and is daily ftrengthened, by filiceous earth, which quits the menftruum on its being cooled, falls down, and being in fomewhat like a foft ftate, concretes (*o*).

From what has been faid it abundantly appears, that filiceous earth is of a faline nature, but differs fo much in degree of folubility, that our artificial limits oblige us to refer it to the earths.

§ vi. *Whether Siliceous Earth be a primitive Earth.*

Thofe earths are called primitive which cannot artificially be refolved into fuch as are more fimple; derivative, thofe which are compofed of two or more primitive earths intimately united : the queftion is then, to which of thefe claffes the filiceous earth may with moft propriety be referred ?—If the queftion was, whether filiceous earth be altogether fimple and homogeneous ? the proper anfwer would be in the negative; for, upon confidering the very probable circumftances above related, concerning the origin of this earth, it appears plainly to confift of two principles, namely, the fluor acid, and fomewhat derived from the water. It cannot therefore be confidered as fimple and homogeneous ; but inafmuch as we are ignorant of the true nature of the primary ftamina of

(*o*) Vid. De Product. Vulcan.

5   water,

water, and as it does not appear that any of the other primitive earths, such as lime, terra ponderosa, magnesia, or pure clay, are derived from the genuine substance of water, it appears that in mineralogy the siliceous earth may properly be considered as primitive, until by apt experiments, both analytic and synthetic, it be demonstrated that the base of this earth entirely agrees with some one of these above mentioned : when this is done, it may properly be referred to the derivatives, but not before ; in the interim, naked conjectures and fallacious observations are not by any means to be confided in. It must be allowed that, to system builders, it will appear more simple to consider all earths as of the same species, with a very few modifications; but it should be remembered, that he who pretends *a priori* to judge of the most compound body in nature, ought first to be acquainted with the whole structure and œconomy of nature.

Some persons, observing that clay acquires by fire a flinty hardness, think that the principles of both are the same ; an opinion which would be established beyond doubt, if siliceous earth, dissolved in fixed alkali, could, by means of the vitriolic acid, form alum, which has been attempted by certain moderns : but this hypothesis, when put to the test of experience, falls to the ground ; for the pure clay is all converted into alum by vitriolic acid, and the siliceous

E 3

earth is not so much as dissolved by that menstruum (§ II and III. A).

Others, because common flints are generally found in chalky hills, imagine, that they originate from chalk, particularly depending upon misunderstood phænomena of gelatinous minerals : these phænomena are explained at large in the treatise on Volcanic Products. In the collection of the Academy, there is found an echinites exactly filled with siliceous earth, and surrounded with the same kind of substance; but the shell itself is still calcareous, and even of a spathaceous form. Now, in this case, since by hypothesis the calcareous earth has acquired a siliceous nature both internally and externally, how could the shell itself avoid the change ? But the nature of the subject, which is still so much involved in darkness, from the want of a sufficient number of experiments, that we cannot certainly determine the origin of siliceous earth, forbids us to dwell longer upon this point.

§ VII. *In what Form Siliceous Earth occurs in the mineral Kingdom.*

The siliceous earth, such as it appears when precipitated from liquor of flints, and freed from all heterogeneous matter, is scarcely ever found, at least in the external strata of this globe; but is, like the other primitive earths, more or less mixed with other substances,

ſtances, and that as well mechanically (as is the caſe in common clay) as by a more intimate connection, and, as it were, ſolution; inſtances of which occur in ſerpentinum, aſbeſtos, mica, ſchoerl, garnet, zeolith, and thoſe ſtones which are called ſiliceous. So long as the ſiliceous nature prevails in the maſs, they are not improperly ſo called, the denomination being taken from the prevalent ingredient: but here we muſt obſerve, that the nature of the compound does not always correſpond with the quantity of the different ingredients; for the properties of certain ſimple earths are far more remarkable and intenſe than thoſe of others. Thus a maſs, in which pure clay makes no more than a fourth, nay even ſometimes leſs, yet preſerves the nature and character of clay; therefore it is that we call ſuch mixtures ſiliceous which ſtand the criteria mentioned in § 11; and, although the ſiliceous nature is ſometimes more obſcure, on account of the quantity and quality of heterogeneous matter, it is of no importance, provided the ſiliceous nature and properties prevail.

To this claſs we may, without reſerve, refer quartz and mountain cryſtal, flints, properly ſo called, and jaſpers; but more ambiguouſly petroſilices and felt-ſpar, as alſo zeoliths, ſchoerls, and laſtly garnets, which are as it were intermediate between thoſe and the gems; which are to be entirely exclu-

E 4   ded

ded from filiceous earths, as not only by
their nature, but by the proportion of their
primary principles, they challenge a place
among the clays, as we shall see hereafter.
Most of the last-mentioned stones abound
in filiceous earths, and contain besides por-
tions of calcareous and argillaceous earth,
yet exhibit the filiceous properties notwith-
standing;—the limits and design of the pre-
sent Work prevents us from mentioning the
specific differences.

DISSER-

DISSERTATION XIV.

HYDROPHANOUS STONE.

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§ 1. *Peculiar Property of the Hydrophanous Stone*.

BENEDICTUS CERUTUS relates, that he had seen with the greatest astonishment, in the possession of Chr. Furleger, an opake stone, which, upon lying in water, by degrees acquired transparency, and which, upon drying in the light, became again opake ; for this reason he denominates it *lapis mutabilis*. Such stones were afterwards very scarce, and had the empty name of *oculus mundi* bestowed upon them. The reason of the former appellation is obvious ; the latter is merely the sport of a

warm

warm imagination. Dr. Hill has very properly called such stones as grow transparent in water *hydrophanous*.

An attentive confideration of the change produced will eafily inftruct us in the nature of this wonderful phænomenon. The tranfparency may be obferved proceeding from the furface to the nucleus ; and at the fame time air bubbles continually arife from the furface of the ftone, and float upon that of the water. Some affert, that the tranfparency begins at the center, and extends itfelf to the furface ; but when that is the cafe it muft be occafioned by fome crack which admits the water at once to the center ; all the hydrophani which I am in poffeffion of, or have ever feen, have, conformably to natural expectation, grown firft tranfparent at the furface.

The phænomena of clouds ferve to fhew that moift particles, copioufly mixed with particles of air, prevent the tranfmiffion of light, and render the mafs more or lefs opake, although the particles of each, feparately taken, are pellucid. The caufe of this is to be fought for in the difference of refracting power ; for by means of that the rays are turned from their original courfe at every particle, a circumftance which is very injurious to tranfparency. A common experiment will ftill more clearly elucidate this point :—the moft tranfparent glafs, when reduced to powder, becomes opake,

becaufe

becaufe the air, which now occupies the interftices, refracts the light much more weakly than the particles of glafs do ; but, upon pouring on water, which difplaces the air, and differs lefs from the glafs in its re-fracting power, a certain degree of tranfpa-rency is reftored. Setting down the fpecific gravity of water 1,000, we fhall find that of air to be 0,001 ; and that of glafs vary-ing, according to its compofition, from 1,791 to 3,380, which is the greateft : hence it appears, that the greateft differ-ence between glafs and water is 2,380, and the leaft is 0,791 ; the greateft differ-ence between glafs and air is 3,379, and the leaft is 1,790. From this calculation we may judge of the different quantities of refraction, and the confequent differences of tranfparency.

Let us now fuppofe a ftone which agrees nearly with water in fpecific gravity, or at leaft is not more diftant from it than glafs ; let us alfo fuppofe that its particles are tranfparent, but that it is uniformly per-forated by invifible foramina, fo that both air and water may be admitted, though not readily ; we fhall then have a ftone, which, when well dried, remains opake, but, like the oculus mundi, grows pellucid in water. The fuperior effect which an alkaline lix-ivium produces in this cafe, depends on the fuperiority of its fpecific gravity.

Although

Although the caufes of this phænome-
non are thus phyfically explained, which
always renders a phænomenon much lefs
furprizing, yet to this effect three condi-
tions, but rarely found united, are necef-
fary; fo that ftones of this kind were very
fcarce, and valued at great and even immenfe
prices. The extravagance of the price alfo
prevented the examination of this fubftance;
and our ignorance of its nature concealed
from us the place where it was to be found;
nay, fo undecided were opinions concerning
it, that the moft acute examiners were
doubtful whether it owed its origin to the
mineral or to the animal kingdom : in the
mean time the curious, both merchants and
philofophers, were bufily employed in fearch
of it. The accounts tranfmitted to the
Royal Academy of Sciences, Stockholm,
were as follow :—

In 1770 the celebrated Quift, who had
vifited England, communicated fome obfer-
vations upon three fpecimens which he had
feen in the Britifh Mufeum ; but as he was
only permitted to examine them fuperficial-
ly, he could not determine their nature.

At the beginning of the year 1774 Mr.
Poetzfch of Leipfic related to the Academy,
that the year before a lapis mutabilis had
been offered at the electoral collection for
the price of 100 ducats ; that this ftone
very much refembled a certain variety of
the Eibenftock opal, which, upon trial, was
                                              alfo

alſo found to grow tranſparent in water: hence he concludes, that the lapis muta- bilis is to be ranked in the family of the opals.

In 1776 Mr. Murray communicated to the academy a diſcovery which had been made three years before by Mr. Veltheim, ſuperintendant of the mines in the Hartz, namely that the grey, green, and yellow hy- drophanæ, are no other than thin cruſts of the chalcedony of Ferro.

In 1777 Mr. M. T. Brunnich, profeſſor at Copenhagan, in a memoir gave a con- firmation of the chalcedony of Ferro's being the matrix of the hydrophanous ſtone: it is ſufficient juſt to mention this; the other circumſtances may be ſeen in the Act. Stock- holm, an. 1777.

Having now mentioned this quality ſo highly prized, and ſhewn its exiſtence in certain of the chalcedony and opal tribe, let us conſider theſe ſtones a little more accu- rately; although it cannot be denied, that the ſame property may, and actually does, exiſt in ſome other ſpecies.

§ 11. *The Opal and Chalcedony compared together.*

The opal and chalcedony agree with one another in many properties.

(A) The common colour of both is fre- quently milky; but the former is more pel- lucid

lucid than the latter ; besides, the opal, viewed with refracted and reflected rays, exhibits different colours ; but this property is not peculiar to it alone.

(B) The chalcedony is of greater specific gravity than the opal ; but in this respect they do not differ much : the Eibenstock opal is from 1,958 to 2,075, and the chalcedony of different countries from 2,559 to 4,360.

(c) The opal does not possess sufficient hardness to strike fire with steel ; the same is sometimes true of the chalcedony : so that, differing only in degree, they may, with respect to this property, be confounded.

(D) With regard to composition, they also agree, as I discovered by the following experiment :—I took 100 parts of chalcedony of Ferro, reduced to a very fine powder by elutriation, and formed it into a little ball, with three times as much mineral alkali, and a small quantity of water ; after mixing them well together, I dried it, and exposed it cautiously to the fire in an iron vessel for an hour and a half ; this operation requires the fire to be gradually raised, but not beyond a certain degree. This management is so difficult, that for once it succeeds the mass melts five times ; for the more alkali is used, the more is the texture of the matter opened, that menstrua

7   may

may extract the foluble parts, but at the
fame time the more is its tendency to fu-
fion increafed ; but the mafs, when fufed,
muft neceffarily be loaded with iron, which
renders an accurate feparation of the princi-
ples very troublefome ; and befides a por-
tion adheres to the veffel, which is not eafily
got off : thefe inconveniences, therefore, muft
be carefully avoided ; and whoever diflikes this
fcrupulous attention to the management of
the fire, muft diminifh the quantity of falt,
and reduce it to a fourth or fixth part of the
chalcedony ; by which means the end may
be obtained, but more imperfectly. The ball,
upon the application of a proper degree of
heat, fplits into a powder ; this powder I
collected and kept in marine acid in a di-
gefting heat, until the refiduum refifted the
force of the acid : the infoluble powder,
which was purely filiceous, when wafhed and
dried, weighed 84 affay pounds ; fo that the
undiffolved part confifted of 16, which, pre-
cipitated and examined, appeared to be all
argillaceous, mixed with fome iron, but
without the fmalleft appearance of any thing
calcareous.

It is proper to obferve, that the fame
chalcedony, without the previous prepara-
tion with alkali, yielded to the marine acid
a portion of argillaceous earth, but four
times lefs : it differs, therefore, from the
common flint, which, treated in this way,

<div align="right">yields</div>

yields fcarce any clay, and is found mixed with calcareous earth, though in lefs proportion than the cryftals of quartz.

I treated the Eibenftock opal in the fame way, and it gave the fame refult as the chalcedony, whether crude or prepared with alkali : the argillaceous part was indeed a few pounds lefs ; but I do not know that the difference is conftant.

(F) From the above it appears plainly, I think, that opal is to be confidered as a rarer and purer chalcedony, and the latter as a denfer and coarfer opal : that the opal is of a more fpongy texture appears not only from the fpecific gravity, but alfo from this, that pieces of the opal often grow more tranfparent and more weighty in water.

§ III. *Of the Hydrophanous Flint.*

We have heretofore confidered the opal and chalcedony ; but thefe, when perfect, do not undergo the change in water of which we are treating, at leaft not in fuch a degree as to attract attention ; but this property is fometimes found in the crufts with which they are covered : thefe we fhall therefore proceed to examine more accurately.

(A) It may in general be faid of thofe filiceous ftones which refemble the common flint in breaking equally and fmoothly,

that

that they are frequently found furrounded with a covering of coarfer materials. I fhall mention what appears probable concerning the origin of this cruft :—evident marks frequently occur, which fhew that thefe ftones have gradually been indurated, and were originally a tenacious mafs. Now, during this operation, the coarfer particles, or thofe more imperfectly diffolved, while the bulk gradually diminifhed, were pufhed to the furface by the more homogeneous matter, or fometimes towards the center, if any cavity be there to receive them ; but as the mafs grew more denfe, the refiftance alfo grew greater, and at length acquired fo much power as to prevent the protrufion, it therefore obliged the protruded particles to fettle in ftrata parallel to the furface ; and thefe ftrata were at leaft diftinguifhable by colour and tranfparency from the reft of the mafs : inftances of this are feen in agates and chalcedonies. The external layers are generally more coarfe, and have un-doubtedly been protruded in the manner above-mentioned, while the mafs was foft. On feparating the layers, each internal is found of a more delicate texture than the adjacent external.

(B) The above-mentioned crufts muft neceffarily differ in texture, denfity, hard-nefs, and gravity ; it is therefore evident, that the three conditions neceffary to the muta-bility required, cannot always be prefent in

thefe. Experience fhews that the proper pieces, which are generally furrounded with thofe that are ufelefs, cannot be diftinguifh-ed by fight, by touch, or any external mark: thofe which, when applied to the tongue, do not fhew any adhefive power, may be re-jected; yet thofe which poffefs that power do not always grow tranfparent in water, al-though they admit it, two other conditions being equally neceffary. Actual immerfion for 24 hours will decide the queftion, as thofe which require longer time are not worthy of attention.

(c) Hitherto we have confidered the crufts of filiceous ftones in general; and although the involucra of all the varieties may per-haps fometimes yield the hydrophanous ftone, yet experience fhews that it is chiefly to be fought for among thofe of a loofe tex-ture, fuch as opals and chalcedonies.

(D) The crufts which grow tranfparent in water, on breaking appear denfe and fmooth, they ftick to the tongue, do not ftrike fire with flint, are of a whitifh yel-low brown, nay fometimes blackifh co-lour: their tranfparency varies according to circumftances; their fpecific gravity fcarce-ly double that of water.

(E) As thefe ftones are deftitute of the hardnefs neceffary to ftrike fire with fteel (a property which is confidered as the crite-rion of filiceous ftones) fome doubt may arife concerning the filiceous nature of the
                                    hydrophanous

hydrophanous crufts : I thought analyfis the moft proper means of folving this difficulty, and upon experiment found the fame principles as before (§ 11. E), which puts an end to all ambiguity. But it appears plainly that the greater or leffer degree of connection between the integrant parts affords a very infufficient and fallacious mark of difcrimination ; and accordingly we find a great variety in this refpect, even in the fame tribe. We have already fpoken of opals and chalcedonies (§ 11. c) ; the fame is true of cornelians, gems (a), &c. We have alfo in clay a very remarkable inftance of the effect of different degrees of exficcation; for this fubftance, although when crude it attracts water ftrongly, and is foftened and penetrated by it, yet by a certain degree of heat it is fo condenfed as to reject water; and at length, by a very intenfe heat, it acquires a perfect flinty hardnefs. In this inftance the very fame matter exhibits very different degrees of cohefion among the particles ; and it is elfewhere demonftrated, that, even when hardened to the greateft degree, it yet retains an argillaceous nature ; we may therefore juftly conclude, that the degree of hardnefs is not to be confided in.

(F) The value of the hydrophanous ftone is eftimated by its bulk, the quicknefs of the change, and the elegance of its colour.

(a) Vid. de Terra Gemmarum.

Of

Of two equally penetrable the larger muft neceffarily grow tranfparent more flowly; but the effect may be fomewhat increafed by diminifhing the thicknefs or perpendicular attitude, the length and breadth remaining the fame. By this method many of them may be brought to grow tranfparent in a few feconds; and no doubt the wonder is much diminifhed, if the change does not take place under the eyes of the obferver: befides, if feveral hours be requifite, neither can the procefs be properly examined, nor are the air bubbles expelled by the water fufficiently vifible.

The colour is derived from iron; now, as that fubftance often differs both in quantity and quality, a confiderable difference muft arife, which generally varies between a yellow and a brown.

(G) That the opal gives admittance to water we have already obferved; but the change is not very remarkable, becaufe it is of itfelf femitranfparent, but if naturally, by fpontaneous calcination, or artificially, by a gentle heat, it contracts an opacity, we immediately get the hydrophanous ftone. To make the opal opaque when dry, by means of fire, requires much caution; for if too much heat be applied, efpecially fuddenly, it flies into fmall pieces.

(H) The change is accelerated by ufing the water hot, as it penetrates the foramina more readily, and the foramina themfelves

are

are more open, on account of the heat; but whether it be hot or cold, the very pureſt water ſhould always be uſed, otherwiſe the ſtone will gradually be obſcured; for any water, though clear as cryſtal, leaves, upon evaporation to dryneſs, an earthy reſiduum. When the water then which has been admitted is gradually diſſipated by evaporation, ſomewhat always remains behind; this, on account of its tenuity, for a long time does not injure the tranſparency, but if the operation be frequently repeated it may at length become viſible; but this may be eaſily removed by acids, if, as is uſually the caſe, it is of a calcareous nature. I am not ignorant that in this operation the colouring particles of tinged liquors are excluded, though the vehicles penetrate the ſtone; but it is equally true that alkaline lixivia penetrate, and of conſequence calcareous and other ſolutions will alſo penetrate.

By concentrated vitriolic acid alſo the ſtone acquires tranſparency, but ſometimes the colour is darkened by the acid remaining in the pores, and growing blackiſh; but this may be removed by an alkali. But the nitrous acid, highly dephlegmated, rather dephlogiſticates than diſſolves the iron of the ſtone, and occaſionally produces various hues of yellow; but as acid menſtrua are able to take up a little of the argillaceous earth as well as the iron (§ 11. E) there is no doubt but, if frequently uſed, they will

F 3   gradually

gradually change the texture of the stone.
The water enters at the first trial more slowly
than afterwards ; it may therefore happen
that a stone which at first scarcely admits
water may, by lying a proper time in acids,
have its foramina opened and dilated so as to
admit it freely.

That the stone when transparent is more
ponderous than when opaque, experience
shews, and the fluid imbibed will easily
explain the cause.

(1) We must not omit mentioning, that
when the hydrophanous stone rendered trans-
parent is exposed to the rays of the sun, or
to an intense light, it frequently shews a
spark or spot shining with peculiar lustre,
which changes to different parts of the sur-
face, according to the situation of the light.
This property, which belongs to opals pecu-
liarly, but not exclusively, is not difficult of
explanation, as the hydrophanous stone is of
the nature of opals ; but is thus far imper-
fect, that when dry it is opaque, when wet
however it grows transparent, and then ac-
quires completely the properties of the opal.
The property is of this nature :—let L M N O,
tab. 2, represent the section of an opal, of a
lenticular or ellipsoid form ; let the parallel
rays of light l m l m, &c. fall upon it,
and a light will appear in the opposite
quadrant above M ; in proportion as the
incident rays are more oblique, the shin-
ing spot is more narrow and more bril-
liant ;

'liant; but the higher the luminous body rifes, the larger and weaker is the fhining fpot. Let a light fall, by means of candles, on both right and left quadrant, and two oppofite fhining fpots will appear, but weaker than the fingle. In open air, in the day-light, the half L M N appears almoft entirely overfpread with a refracted light, but indefinite, not exhibiting any figure; yet when light is admitted into a chamber through a hole in the window-fhutter, the fhining fpot reprefents the figure of the hole: it alfo reprefents the figure of the flame, and that in an erect fituation, if 1 reprefents a lighted candle or the fun itfelf; therefore the adjacent rays, coming from the fame points, are refracted within the ftone, and form the figures of thefe points. When the incident rays are nearly parallel to the plane N Q, two or more curves of that kind called *cauftic by refraction* diverge from M to the internal parts: thofe which arife from refraction from the oppofite convex part o L are feen within the ftone, but thofe which are generated by refraction in the concave part L M N are extended beyond the ftone, in the plane N Q. In order to obferve thefe phænomena diftinctly, let the lighted candle l be placed at a foot diftance from the perpendicular R P, paffing through the eye at R, placed about half a foot higher than the flame; then let an ellipfoid opal be held upon the finger, or a card, at

F 4   the

the diſtance of an inch from the flame, and
the cauſtic curves will appear : if the ſtone
ſinks ever ſo little in the line N s, parallel
to R P, a refulgent point will appear within
the maſs at M, of the colour of the ray
which paſſes through it : but at o, or the
ſurface, a white ſpot appears ; when it de-
ſcends a little lower, in the ſame right line,
the points change into flaming figures ; at o
a white and leſſer one ariſing from reflexion ;
at M one coloured, and larger, which ariſes
from refraction ; theſe two, upon the fur-
ther ſinking of the ſtone, riſe and meet toge-
ther at L : by uſe we may eaſily learn to pro-
duce any of theſe varieties, unleſs the figure
of the ſtone be improper, as upon this de-
pends both the number and the differences
of the curves.   The colour of the figures
which ariſe from refraction muſt neceſſarily
be the ſame with that which the ſtone
tranſmits ; for it is known that opals ſeen
with reflected and refracted light exhibit dif-
ferent colours : the mountain cryſtals, and
other colourleſs pellucid ſtones, however
ſuitable their form, do not exhibit theſe
phænomena diſtinctly : certain vague col-
lections of light may be ſeen, but a peculiar
colour is neceſſary to diſtinguiſh the form
of ſuch appearances : this colour is here
wanting, as all ſpecies of rays are tranſ-
mitted.

The nature of our ſubject forbids the in-
troduction of any thing more geometrical,

as

as what has been faid is fufficient to explain the true nature and origin of thefe luminous points. We fhall only add, that the ftars which appear on the furfaces of fphærical pellucid ftones by a particular fituation with refpect to the light, are generally nothing more than a number of thefe cauftic curves proceeding from the fame point—to this perhaps may be referred the afteriæ of the ancients.

(κ) The cruft of that ftone which Born calls the *fpathum piceum*, according to his obfervations, fometimes grows tranfparent in water, and is akin to the opals in its loofe texture, its not ftriking fire with fteel, in breaking fmooth, and other external marks. Upon analyfis I found it for the moft part a pure filiceous earth, with a little clay ; and an exceeding fmall portion of lime.

§ iv. *Of the Hydrophanous Steatite.*

Although this mutability is chiefly found in the filiceous ftones of a loofer texture, it muft not be confidered as peculiar to them alone. The conditions neceffary for this purpofe may alfo be found in the other tribes, as we fhall here prove by an ex-ample.

The fteatites vary much, both in colour and fubtlety of parts, as is well known. In

this

this fpecies alfo there fometimes occurs a
ftructure of fuch a kind as to admit water;
and as more than half the weight confifts of
filiceous particles, frequently pellucid, it
may be eafily underftood how this may be
rendered more tranfparent : but the hydro-
phanous fteatites, being loaded with magne-
fia, feldom attains the fame degree of tranfpa-
rency as thofe which confift entirely of fili-
ceous earth, which are alfo more hard, tho'
they yield in beauty and variety of colour
to the others.   Dr. Brückman mentions
red, white, grey, and green fteatites, poffef-
fed of this property; thefe he directs to be
prepared firft by boiling in an alkaline lixi-
vium, and then in vinegar.

Experiments, if fufficiently multiplied,
will doubtlefs difcover hydrophanous ftones
in other fpecies.

DISSERTATION XV.

OF THE

EARTH OF GEMS.

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§ 1. *Various Opinions concerning the Earth of Gems.*

FROM the moſt remote ages, the tranſ-
parency, the ſplendor, the colour, and
hardneſs of gems have attracted the atten-
tion of mankind, ſo that, not only in the
time of Theophraſtus the Ereſian, they were
dignified by the name of precious ſtones;
but in our days this product of the mineral
kingdom is very dear, and not to be had but
at an enormous price: but although it is
very reaſonable to admire, with Pliny, the
perfection of their nature; yet, to the bulk
of mankind, more ſolicitous about external
glitter than internal perfection, they have
rather

rather fuggefted the idea of making them fubfervient to vanity and luxury, than that of examining their real perfections. Their fcarcity and extreme dearnefs for a very long time prevented them from being accurately examined, from whence it often happened that the wealthy paid dear for their ignorance, purchafing the fpurious or artificial gems as genuine.

In the mean time mineralogifts included them in their fyftems; but as they trufted too much partly to external appearances, partly to other fallacious marks, it was impoffible but they muft difagree about the arrangement; and certainly, fo long as their analyfis was not underftood, no man could (unlefs accidentally) affign their true places, as long as it was unknown whether their earthy bafe was fimple and primitive, or compound and derivative. Such as rank the gems among faline bodies, regard chiefly their figure; but thefe men do not confider that determinate forms by no means depend upon faline nature (although fubftances which are foluble in water are in a particular manner difpofed to cryftallization) inafmuch as metallic, inflammable, and earthy bodies, afford cryftals, and thofe not unfrequently of a very beautiful kind; and in general the property of cryftallizing feems to belong to every folid body, provided its particles be fo fubtilely divided and fufpended (either in the dry or the humid

mid way) that while they are again concret-
ing they may be at liberty to obey their
mutual attraction, and affume a fymmetrical
fituation : in falts themfelves the fpecies of
figure depends not upon the acid, nor yet
upon the bafe which is united to it. The
vegetable, as well as the mineral alkali, with
marine acid affumes a cubic figure ; but the
fame acid, with volatile alkali, terra ponde-
rofa, mercury, bifmuth, cobalt, and other
fubftances, affumes forms of a very different
kind. If therefore in this cafe the acid
has no effect, how will it act when it can-
not be diftinguifhed by any experiment, but
its prefence is inferred by bare conjecture ?—
The fame may be faid of the bafe ; for each
alkali, with different acids, yields diffimilar
cryftals. Alum and falited cobalt, when
properly cryftallized, yield octaedra, a figure
which neither correfponds with the men-
ftruum nor the bafe ; and what are we to
think of the pyrites, which occafionally
exhibit every one of the regular geometrical
figures ?—but we have no need of multiplying
examples, if that be known, which I think
has been already fufficiently demonftrated,
namely, that from a few primitive forms
of the fame fubftance, a great many deriva-
tives, and thofe very diffimilar, may arife.
Thefe things being confidered, I do not fee
with what propriety the diamond and the
ruby are affociated with alum, of which they
do not fhew the flighteft veftige : but if,

after

after all, we are rather to truſt to occult principles, on this foundation we may make alum of ſalited cobalt, and the other octaedral ſalts. On this hypotheſis too the cubic diamond would be enumerated along with ſea ſalt; and that which is an hexagonal priſm, terminated at each end by three rhombi, among the ſchoerls.

Thoſe who rank the gems among vitreſcible ſtones, beſides various negative criteria of leſſer moment, maintain that they have a gloſſy appearance, and that, in fuſion with fixed alkali, they run into a pellucid glaſs; the former of theſe circumſtances is very fallacious, the latter indeed refers to a quality more eſſential. But we ſhall ſee hereafter what experiments ſhew on this head: hardneſs is in general but a very vague mark, as it often depends entirely upon the degree of exſiccation, the ſubſtance ſtill remaining the ſame, as appears ſufficiently in ſoft clay, when well burned. What ſome call vitreſcent earths, others denominate ſiliceous; but names change not the nature of things, thoſe being the beſt which are adapted to it.

In drawing up a ſyſtem of mineralogy, if the figure, texture, hardneſs, colour, tranſparency, magnitude, and other external appearances, were every where and always ſufficient to diſtinguiſh mineral bodies, this would perhaps (to beginners) be the moſt eaſy method, but it ſtill would not be the

beſt,

beft, as thefe properties of bodies, which are applicable to human purpofes, are derived from the nature of the conftituent parts, and but rarely from the external appearance. No one is ignorant how fallacious fuperficial characters are, at leaft no one who has the leaft idea of modern mineralogy.—But fuch is the condition of man, that when he is led by the hope of fuccefs to attempt impoffibilities, a long time paffes before he returns to wifdom.

Among the moft modern fyftems of mineralogy the moft perfect by far is that of the illuftrious Cronftedt, a fyftem which he propofed with fo much modefty as to conceal his name. In this all the fubftances are arranged according to their principles : if he fometimes confiders thofe as fimple which in reality are compound, it is not to be laid to his charge, as thefe errors proceeded not from a defect in his plan, but from the want of a fufficient number of experiments :—if he has not every where found out the right path, he always feeks it with candour, and defcribes it with precifion. Treading in his fteps, I have for many years laboured in the analyfis of the mineral kingdom, in queft of the foundations for a fyftem of natural hiftory, more expreffly adapted to the improvement of natural philofophy, and the advancement of public and private utility.

In various little effays I have, in a curfory manner, mentioned the conclufions drawn
from

from my experiments: in this place I am especially to treat of gems, in which class those crystals only are generally ranked which very much exceed the mountain crystals in hardness.

§ 11. *Habitudes of the Gems examined by the Blow-Pipe.*

The tube which goldsmiths use for soldering, and which is employed by a few other artificers, is well adapted for experiments in mineralogy; its usefulness and convenience recommend it much, as I have at large mentioned in a treatise on that instrument. This is of the greatest use in the examination of gems, as the smallest pieces that can be taken up by a forceps (which in this case are sufficiently expensive) will serve for these experiments.

It is necessary at the very first to distinguish the diamond from the rest, as it is much harder than them, and also differs in other particulars.

Powdered diamond, exposed to the flame on a piece of charcoal, soon grows white, but scarcely undergoes a sensible change, as it is difficult to keep up the flame constantly for so long a time as is necessary to resolve it into vapour; while at the same time, for so long a continuance it is scarce possible to avoid some small inequality in the blowing, which will scatter it about; in

7   this

this refpect other gems entirely agree with the diamond.

In order to obtain folutions of minerals by the *via ficca*, I employ chiefly three different kind of falts, namely, an acid, an alkaline, and a neutral. I am not acquainted with any acid which can endure the fire upon charcoal, except that of the microcofmic falt: this falt is neutral, but triple, containing both the volatile and mineral alkali. The phofphoric acid, faturated with volatile alkali, cannot be brought to cryftallize; which yet always happens, upon the acceffion of a proper quantity of mineral alkali, and the triple falt which refults from hence is commonly called microcofmic falt. Upon fufion on the charcoal, this fends forth its volatile alkali, fo that the portion of acid which had been before faturated with it, being now fet at liberty, is the better able to exert its effects upon other bodies. I make choice of the mineral alkali well depurated; the vegetable, on account of its deliquefcence, is lefs proper. Of late I make ufe of borax, as being a falt nearly neutral, both the principles of which are fixed in the fire, and are much difpofed to vitrification.

I have tried the effects of thefe falts upon the gems:—the microcofmic falt attacks them with difficulty, yet diffolves them; and with refpect to this falt, there is a remarkable difference between the diamond

and all the other gems ; for a fmall piece or a very fubtile powder of it, immerfed in a globule of this falt in fufion, during the fufion immediately floats upon the furface, at firft fending forth flowly a few bubbles, which, upon continuing the operation, entirely ceafe. If the apex of the flame be kept conftantly on the powder, it is gradually diminifhed, but is partly confumed by the fire, partly diffipated by the blaft, and the refiduum, which is very fmall, perhaps diffolved. The particles of the other gems enter into, and remain in the fufed falt without effervefcence ; they wheel circularly about with great velocity, and are by degrees taken up, yielding water-coloured globules, unlefs when they are coloured, which, on vitrifying, they fometimes are, efpecially when hot.—Thefe gems therefore are fixed to the falts by a more powerful attraction than the diamond, which on the contrary fhews a fort of repulfion.

The mineral alkali, fufed in a filver fpoon [charcoal abforbs it] takes up the fmalleft particles of gems, and notwithftanding a long continued flame fcarcely diminifhes them ; yet the emerald is refolved into a powder, but a refractory one. The diamond feems to elude its force altogether, as will appear from what follows.

Borax diffolves them almoft in the fame manner as microcofmic falt, but fomewhat more quickly, and without any effervef-

2   cence ;

cence; but the diamond is more weakly attacked, fo that after a long-continued fu- fion the globule adheres to the charcoal, and the powder lying on the furface is in the mean time diffipated.

The powdered diamond, before it is ex- amined, muft be depurated by aqua regia, for all that which is for fale abounds with heterogeneous matters, as we fhall fee here- after (§ 111. B). As the diamond exceeds all the reft in hardnefs, as it is by fire diffi- pated into fmoke, and in all its habits dif- fers from the reft, which in general agree with one another: thefe fhall in the future be fpecifically comprehended under the name of gems.

The habits above defcribed, efpecially thofe with the mineral alkali, diftinguifh the gems very completely from the moun- tain cryftals, which are not only taken up by alkali, but alfo with a vehement ebulli- tion or effervefcence: thofe artificially made, which confift of an hyaline, or coloured glafs, immediately betray themfelves, by fufing without any addition.

Hence it appears that the diamond and the gems form genera as much diftinct as quartz, garnet, fchoerl, and many ftones; yet it remains to be examined, whether the earthy bafe of each be primitive or derivative; and if the latter be the cafe, what fimple ele- ments, and in what proportion, conftitute it?—Thefe queftions cannot be anfwered

but

but by the *via humida,* to which we ſhall therefore have recourſe.

§ III. *Cautions to be obſerved, and Difficulties occurring in the Analyſis of Gems.*

In this examination many obſtacles oc-cur, the chief of which we ſhall conſider ſe-parately.

(A) The dearneſs of the matter not only perſuades but obliges us to uſe ſmall quan-tities; and in the operation we muſt be very cautious to avoid the loſs or addition of any thing, as in an experiment on ſo ſmall a quantity the leaſt difference is of great conſequence, though in a larger quantity it might be almoſt entirely neglected.

(B) Pulverizing the gems is attended with many inconveniences; they are poſ-ſeſſed of ſuch a degree of hardneſs that they are in this reſpect ſuperior to all other bo-dies; when immerſed, red hot, in cold wa-ter, they become ſcarcely more friable, though by this method the moſt ſolid moun-tain cryſtals are very eaſily comminuted. Struck by the hammer on an anvil the grains of mountain cryſtal ſplit in general, but the fragments often fly about; and as to the diamond it frequently penetrates both the anvil and the hammer.—The diamond-powder which is for ſale contains heteroge-neous matters: from that which I got from the Baron Alſtromer, and which had been
lately

lately brought from Antwerp, aqua regia extracted 0,12, without the affiftance of heat: the menftruum thus loaded was yellow: fixed alkali threw down a whitifh powder, which, expofed alone to the blow-pipe, melted into an opake globule of a metallic appearance; this effervefced with lime, with borax, and microcofmic falt; but the globule, with microcofmic falt, when loaded with a certain quantity, grew red on cooling, paffing in a fingle inftant from the moft fplendid reddifh tranfparency to opacity. There is no doubt but that this foreign mixture is owing to the inftruments made ufe of, for which reafon the powdered diamond is fold at a fmaller price than pieces of diamond fo fmall that they are of no ufe but for pulverization.

The other gems are much more eafily comminuted, and at length may be united with water; while the pure water is milky, it is to be carefully decanted, and frefh poured on repeatedly, until by degrees the whole mafs has acquired fuch a degree of fubtilty, that it can remain fufpended, though remaining at reft for fome minutes. The moft extenfive furface poffible is neceffary, that the menftrua may be able to loofen the clofe connection of the primitive principles; but as the agate is much inferior in hardnefs to the gems, fomething of the filiceous earth muft neceffarily be abraded, even by the moft gentle triture, which

G 3   is

is mixed, and, although known as to its na-
ture, nearly unknown as to quantity, un-
lefs by weighing the veffel exactly before and
after, efpecially if it be convenient to make
experiments upon fmall quantities only.

(c) It is not a little difficult to pro-
cure fuch veffels as are fit for thefe ex-
periments in the dry way. The common
crucibles have rough furfaces filled with
little holes, which hide a quantity of the
matter very confiderable where experiments
are made upon minute portions ; and what
is ftill worfe, they confift of argillaceous
and filiceous earth mixed, which muft ren-
der our conclufion fallacious and uncertain,
efpecially when fixed alkali is ufed. In or-
der to difcover the effect produced by this
circumftance, I made the following experi-
ment :—a fmall Heffian crucible, exactly ba-
lanced, weighed 1,585 affay pounds ; into
this I put 100 of dry falt of tartar, and ex-
pofed it for 37 minutes to a melting heat ;
but upon cooling I found no more than
1,645 ; fo that 40 pounds had flown off,
owing, no doubt, to the aerial acid and the
moifture ; the former adhering to the al-
kali, the latter both to the falt and the
crucible. The fufed pellucid mafs at the
bottom at firft refembled a glafs, but was
by degrees obfcured by attracting the wa-
tery vapours from the atmofphere : this I
firft wafhed with warm water, which, when
decanted off, formed a jelly ; when well
wafhed,

wafhed, firft with vitriolic acid, then with warm water, and dried, it weighed 12 lb. which, upon examination, appeared to be altogether filiceous. The folution precipitated by fixed alkali, gave 6 lb. of earth of alum; befides, the crucible was remarkably corroded, particularly about the furface of the fufed mafs. Hence the particles and fragments which were feparated in the wafhing, when dried weighed 10 lb. but the crucible itfelf, well wafhed and dried, now weighed 1,594 lb. which is greater than its weight when new; therefore, as $12 + 6 + 10 = 28$, and $1,585 - 28 = 1,557$, and $1,594 - 1,557 = 37$, it is manifeft, that during the fufion the fixed alkali had extracted 12 lb. of filiceous earth, that is nearly $\frac{1}{8}$ its own weight, and 6 of clay, or nearly $\frac{1}{16}$; and that befides the crucible retained 37 lb. of fixed alkali, which covered the bottom with a vitreous cruft not at all foluble in water: thefe circumftances fhew plainly, that we muft not truft to the crucible in decompofing the feveral genera of earths by the dry way, as it will fuperadd heterogeneous matters, or at leaft change the proportions of the principles.

In the examination of quartz, I have for many years made ufe of the iron difhes which are defcribed in the Treatife de Terris Geoponicis. It is well known, that the common rods of this metal are of a parallelopiped

G 4

lelopiped form, two of whofe oppofite fides
are broader than the other two ; I made
choice of forged iron of the beft kind ;
the rod I had cut into pieces of an inch
in length, and on each of the broader fur-
faces I hollowed out a fegment of a fphere ;
in thefe cavities, when cleaned and polifh-
ed, I put the mixtures with alkali, and
by an iron cover prevented the falling in of
afhes and coals. I alfo made trial of another
metal, namely, platina precipitated from
aqua regis by fal ammoniac, and afterwards
fufed by microcofmic falt, and then formed,
by hammering, into a little cup ; but the
large pieces of regulus obtained this way
were brittle, and none but thofe which
were very fmall were fo perfectly fufed as
to be malleable. The little cups made of
this metal could therefore only contain a
few grains ; but if they can ever be ob-
tained of a proper fize, they will be in all
refpects the beft, as being infufible by fire ;
and if at firft they be fufficiently boiled in
marine acid, the maffes afterwards fufed in
them will not be adulterated with any iron ;
they may indeed be elixated by any acid
menftruum, except aqua regis.

If the mineral earths are fufed in iron
difhes, by means of alkaline falts, a confider-
able quantity of the iron is mixed with
them, which renders the feparation of their
primary principles extremely difficult ; but
by a proper regulation of the degree of fire

the

the defired end may be obtained without any inconvenience, as we fhall hereafter fee.

(D) In thefe experiments it is neceffary to have the menftrua much purer than they are generally found. The vitriolic acid which is for fale is adulterated with a variety of heterogeneous matters, and among others fometimes with gypfum and vitriol, which occafions a confiderable difference in enquiries fuch as ours. No other, therefore, is to be employed but fuch as has paffed over from a low cucurbit by a gentle diftillation.

The other acids too require to be depurated by a peculiar diftillation, for it is particularly neceffary that they be freed from all earthy or metallic mixture, as fuch muft confound the quantity and quality of the principles which are explored by the analyfis.

The common alkali of tartar is always adulterated with filiceous atoms, the weight of which frequently amounts to 0,02 ; thefe in the ftrong acids immediately are feparated, but being united with the alkali, remain in the watery folution until the menftruum has attracted aerial acid from the atmofphere, which proceeds very flowly ; for this reafon, in experiments which require much accuracy, I ufe no other alkali than the mineral well depurated, or the vegetable extracted by diftilled water from cream of

                                                tartar

tartar in a well-burned glafs veffel, which
manifefts no figns of filiceous earth.

§ IV. *Power of Acids in decompofing the Gems.*

There are only yet difcovered five fpecies
of earths, which are fo fimple that they
cannot, by any means hitherto known, be
refolved into more fimple ones, nor be
tranfmuted one into the other; thefe are
therefore called primitive earths, and that
with juftice, until new experiments evince
the contrary :—thefe are terra ponderofa,
lime, magnefia, argillaceous and filiceous
earth. It cannot be denied that it is not
altogether without probability fome ima-
gine that the number of thefe earths fhould
be diminifhed, confidering them all as mo-
difications of one; but in the explanation
of nature, we muft not fo far indulge con-
jecture, as to fuffer the vain phantafms of
imagination to prevail over phænomena con-
firmed by conftant experience, and not im-
peached by a fingle experiment, when made
with accuracy. Four of the above-men-
tioned earths are foluble in certain acids;
the fifth alone rejects all acids, except that
of the mineral fluor. If, therefore, fome of
thefe, in greater or lefs number, be united
into one mafs, chemiftry is able to feparate
them all by the ufe of appropriated men-
ftrua : enlarging the furface of contact affifts
                                            the

the action of the menstruum very much,
the earth must therefore be reduced to a
very subtile powder. Sometimes, however,
mechanical division is not sufficient, and
the operation must be performed chymi-
cally, which, in the present instance, is done
in the dry way, by means of an alkaline
salt, which by attacking the siliceous earth
loosens the connection of the principles—to
what degree the use of mechanical pulve-
rization alone may be carried, we shall soon
see.

(A) Vitriolic acid did not attack the dia-
mond in any way in which I have hitherto
employed it; but I must confess, that I
made use only of very small portions: I
chose the smallest fragments of the thinnest
lamellæ, being very reasonably distrustful of
the powder which is for sale. A double
weight of vitriolic acid, highly concentrat-
ed, added to a very subtile powder of the
other gems, and afterwards discharged by
boiling to dryness, operates very power-
fully; for the residuum, elixated with warm
water, yields not only a metallic colouring
substance, but a small portion of lime : the
metallic part, precipitated by a phlogisticat-
ed alkaline lixivium, yields a beautiful Pruf-
sian blue; so that from hence it clearly ap-
pears, that the red colour of the ruby, as well
as the blue of the sapphire, the yellow of the
topaz, the tawny of the hyacinth, and the
green of the emerald, is to be attributed to
iron;

iron; the quantity of which I determined by
that of the blue precipitate. As I have elfe-
where (b) demonftrated, that fix parts of the
Pruffian blue are obtained from one of the
diffolved iron, I precipitated the calcare-
ous matters with an alkali, and it was found
fo pure, that with vitriolic acid it did not
fhew the fmalleft traces of argillaceous
earth, except in the decompofition of the
fapphire. Below are found the quantities
extracted from 100 affay pounds, expreffed
in hundredth parts, or fingle pounds.

		Aerated lime.	Iron.
The ruby, red -	- oriental	9 —	10
. fapphire, blue -	oriental	7 —	2
topaz, yellow —	Saxon	8 —	6
hyacinth, tawny -	oriental	20 —	13
emerald, green —	oriental	$8\frac{1}{2}$ —	4

By this method all the calcareous earth
and iron are extracted, as will appear here-
after.

(B) Concentrated nitrous acid, by digef-
tion and decoction, yielded nearly the fame
refult; I ufed eight times the quantity of this
menftruum, continued the digeftion for two
days, and the boiling for an hour; I cau-
tioufly decanted off the clear liquor, and
poured on again the fame quantity of men-
ftruum, digefted, and then boiled it: this

(b) De Min. Doc. hum.

operation

operation I repeated twice more, and then ftopped, as the laft liquor contained very little diffolved matter.

Thefe liquors, collected and precipitated, gave nearly the fame refult as mentioned in A, at leaft with regard to the lime; and in the iron the difference never exceeded 0,02. The nitrous acid, efpecially when affifted by heat, dephlogifticates the iron, and in that cafe takes it up with great difficulty: hence too, in this experiment, the iron was mixed with a little ochre.

The diamond rejects this menftruum as well as the former.

(c) I employed the concentrated marine, as well as nitrous acid; and with the fame fuccefs, except that it extracted the iron better than even vitriolic acid, but the difference did not exceed 0,01.

We fee, therefore, that from the gems properly fo called a fmall quantity of lime and iron may be extracted by acid menftrua; but as what is extracted fcarcely amounts to $\frac{1}{5}$ of the whole, and after the feparation the refiduum is nearly of the fame nature as before, I began to conjecture that the extracted part is accidental, and that the refiduum conftitutes the particular primitive earth; and this is an opinion which I have publifhed in other works. In the mean time, however, the few veftiges of argillaceous earth which are extracted from the fapphire, and which fometimes amount to

0,02,

0,02, ftarted a fcruple of great weight; as I had often before experienced that bodies which, notwithftanding the moft fubtile mechanical pulverization, appear infoluble, yet upon being diffolved in another men-ftruum are afterwards actually taken up by the very menftrua which before were inef-fectual: I therefore tried in many ways to effect my purpofe. One part of alkaline falt, by means of a due degree of fire, reduces two parts of quartz or flint to a tranfpa-rent ftrong glafs; but as the proportion of falt is encreafed, the glafs becomes the worfe, and is not only corroded by acids, but, if it contains a double quantity of falt, deli-quiates in the open air: by this method a glafs may be had foluble in water. The gems could not heretofore be reduced to tranfparent maffes by means of alkali, and a quadruple quantity of falt is requifite to make them coalefce in fufion to a certain degree; but as this operation cannot fafely be performed but in iron veffels, in which cafe the mafs not only adheres obftinately to the veffel, but is at the fame time loaded with iron, this method is liable to great in-conveniencies; but upon trial I have found that fufion is not neceffary, and that the purpofe is equally anfwered, if the quantity of alkali be fuch that the particles may co-alefce by an incipient fufion. Hence re-fults a method which I have found extreme-ly convenient in the examination of mine-
                                                        rals,

rals, the application of which to the gems
I am now to defcribe.

§ v. *Method by which the proximate Prin-
ciples of Gems are moft eafily determined.*

(A) The gems are to be reduced to a
moft fubtile powder, which may be effected
by trituration and elutriation.

(B) A determined weight of this powder
(the larger the quantity the better) is to be
mixed with double its weight of depurated
mineral alkali which has undergone fponta-
neous calcination.

(C) Let the mixture be put into an iron
difh, the infide of which fhould be fmooth
and polifhed, left the fmall pieces, which by
calcination eafily feparate from the metal, be
mixed with the contents of the veffel.

(D) Let the difh be placed in a wind-
furnace, upon a tile, and covered by an in-
verted crucible, to keep off the coals and
afhes.

(E) Let it be kept moderately hot for
three or four hours; if the heat be too great
the mafs adheres to the bottom of the veffel:
a blaft is not to be employed, left the iron
fhould fwell, and go off in fcoriæ.

The firmnefs and coherence of the mafs,
and its being eafily feparable from the veffel,
without any mixture, fhew that the fire has
been properly regulated; which may be eafily
learned by a few trials.

(F) Let

(F) Let the mass, carefully separated from the vessel, be powdered in an agate mortar; and let all that is soluble be extracted from it by marine acid, in a digesting heat.

That nothing more remains to be extracted, may in some measure be judged by the light and spongy nature of the residuum, but more certainly by the addition of a new portion of acid, which, when digested for several hours, does not take up any thing.

(G) The solution being finished, the residuum is collected and washed well, dried, and weighed. The deficiency of the former weight determines the quantity dissolved.

(H) The solution is yellow, which indicates the presence of iron : this is yet more certainly manifested by an alkaline phlogisticated lixivium, and therefore the solution should be first precipitated by this, properly saturated. The Prussian blue is collected, washed, and dried ; the sixth part of which indicates the quantity of iron.

(I) The earth, freed from all the metallic parts, is precipitated by a fixed alkali, purified completely from siliceous earth : let the precipitate, washed, dried, kept red hot for half an hour, and then weighed, be plunged into six times its weight of distilled vinegar, which in the cold, in the space of an hour will dissolve all the lime, magnesia, or terra ponderosa, which is present ; but

does

does not take up any confiderable portion of clay, unlefs by a long digeftion.

(K) The vinegar filtered, yields to an aerated fixed alkali all the earth which it held diffolved, which muft be edulcorated and weighed. I mention particularly an aerated fixed alkali, as fuch an one precipitates even terra ponderofa, which eludes the cauftic alkali.

(L) The nature of the precipitate thrown down from the vinegar is next to be examined: if this be put into diluted vitriolic acid, the middle falt generated will readily determine the bafe; for with terra ponderofa this acid generates fpathum ponderofum infoluble in warm water, though a thoufand times its quantity. With lime it produces gypfum, which excites fcarcely any fenfation of tafte, and diffolves in five hundred times its weight of warm water, but is immediately thrown down from this folution by acid of fugar in the form of faccharated lime. With magnefia it forms Epfom falt, extremely bitter, foluble in its own weight of warm water, and quickly deftructible by lime-water.

(M) The refiduum collected (G) muft alfo be examined, which is beft done by the blow-pipe: thefe refidua, in fmall portions, muft undoubtedly be very minute, and therefore fhould not be treated in large veffels: befides, the ordinary crucibles are by no means fit, where filiceous earth is con-

cerned, nor are veffels of iron fafely to be ufed, as fufion is neceffary (§ III. c). Thefe infoluble refidua are found to confift either of particles of gems not yet fufficiently divided, or of filiceous earth, as all the other earths yield to the force of the acid.

This operation is eafily performed by the blow-pipe, in the following manner :—let a piece of mineral alkali be fufed in a filver fpoon, and to it be added a fmall quantity of the refiduum ; the circumftances of their union are then to be carefully obferved, for if the refiduum enters the fufed alkali with a vehement effervefcence, and is all quickly diffolved, it is truly filiceous ; but if it enters without effervefcence, and afterwards continues rolling about in form of a powder (which, as the fufed mafs is tranfparent, may eafily be feen) we may conclude that there ftill remain in it fome particles of the gem.

(N) The refiduum mentioned (L) has been alledged to be argillaceous ; but to demonftrate this, let it be treated with thrice its weight of concentrated vitriolic acid, fo that the liquor may evaporate to drynefs ; the remaining mafs, if the bafe be argillaceous, will diffolve in twice its weight of warm water, produce a fweetifh aftringent tafte in the mouth, yield octaedral cryftals, be quickly precipitated by cauftic volatile alkali, and exhibit the other characters by which alum is diftinguifhed.

§ VI. *Proxi-*

§ vi. *Proximate Principles of the Gems.*

I have examined the gems in the manner above defcribed:—the refiduum of G I found purely filiceous ; the precipitate of H, a genuine Pruffian blue ; that part diffolved by diftilled vinegar in K, wholly calcareous ; and what remained undiffolved, argillaceous: fo that I entertain no doubt concerning the quality of the principles. As to the quantity and relative proportions, many experiments are neceffary to determine that point ; for I have only ufed very fmall quantities, not exceeding an affay hundred. Upon fubjecting the matter of the fame cryftal twice to experiment, a difference occurred fcarce exceeding $\frac{1}{100}$; but different cryftals, *v. g.* different rubies, differed more, even to 0,07. Doubtlefs in every fpecies the proportions may vary a little, within certain limits, which yet remain to be difcovered.

Here follow the mean quantities extracted from each 100, according to my experiments : as the argillaceous earth forms the largeft part of all of them, I have arranged them according to the quantity of that ingredient.

	Clay.	Siliceous Earth.	Lime.	Iron.
Emerald	60	24	8	6
Sapphire	58	35	5	2
Topaz	46	39	8	6
Hyacinth	40	25	20	13
Ruby	40	39	9	10

By

By clay I mean nothing more than the
earth of alum, which is found in all clay
mixed with filiceous powder (§ v. N).
By filiceous earth I underſtand ſuch as
principally conſtitutes pure quartz, moun-
tain cryſtal, and flints (§ vii). The num-
bers in the third column point out aerated
lime: a doubt may indeed be ſtarted, whe-
ther it enters into the compoſition pure or
aerated ; if the latter be the caſe, the cloſe-
neſs of its connection with the other prin-
ciples, and the ſmallneſs of its quantity,
which never exceeds $\frac{1}{6}$, and is in general leſs
than $\frac{1}{10}$, may be ſufficient to prevent any
diminution of weight in the fire, or any vi-
ſible efferveſcence with acids ; but the de-
ficiency of weight which nevertheleſs oc-
curs ſeems to indicate that it enters the
compoſition aerated. Out of 100 parts one
or two are eaſily diſſipated in the various
operations in different veſſels and filters ;
which accounts for ſome of the deficiencies
in the above table ; but 5, 8, and much
leſs 12 parts, could not eſcape proper accu-
racy in that analyſis, which laſt would be
the caſe in the decompoſition of the hya-
cinth, on the ſuppoſition that the lime was
preſent free from aerial acid. I could ob-
ſerve nothing volatile, after an expoſition of
ſeveral hours to a white heat, nor upon the
addition of acids is any thing ſublimed
while they paſs over into the receiver.

The

The laſt column ſhews the quantity of metallic iron, which, diſſolved in acids, and precipitated by phlogiſticated alkali, yields a quantity of dark Pruſſian blue, equal to that obtained from the ſeveral gems reſpectively (§ v. н). Now the iron is here preſent in a calcined ſtate, and this metal, like others, has its weight increaſed by calcination, ſometimes amounting even to 0,36 : hence it follows that the quantity of martial ingredients is ſomewhat greater than is denoted by the numbers ; and this metal gives birth to different colours, not only in proportion to its quantity but its quality, that is, the quantity and modification of the phlogiſton remaining in the calx.

From the above it may alſo be collected, that the gems agree in this reſpect ; that they all conſiſt of the ſame principles ; and that of theſe the argillaceous earth forms the greateſt part, then the ſiliceous, next the calcareous, and leaſt of all the iron ;—the two firſt ingredients vary extremely.

The knowledge of the principles muſt neceſſarily throw ſome light on the properties. Theſe gems exceed all other bodies in hardneſs, the diamond excepted ; and we find upon analyſis, that they abound in argillaceous earth. Hence we may form ſome judgment of the prodigious degree of exſiccation requiſite to occaſion ſuch a degree of hardneſs. The heat of the temperate zone is found inſufficient for this purpoſe, and

H 3   the

the more conftant and intenfe heat of the tropical climate is requifite : condenfation is the neceffary confequence of this hardnefs, hence the gems are more ponderous than the other earthy cryftals.

The gems, except emerald and hyacinth, refift the moft intenfe fire; yet we know that the ruby has been foftened in the focus of a burning mirror. Experience alfo fhews, that the four principles of which they are compofed, according to their various proportions, form mixtures with very different degrees of fufibility : fixed alkali attracts filiceous earth very powerfully, but fcarcely acts upon argillaceous earth or lime; hence it is with difficulty it acts upon the gems in which not only the filiceous earth is in fmall quantity, but is alfo clofely united with the other principles ; yet in the emerald, which is inferior in hardnefs to the reft, the loofer texture permits the alkali to attack the filiceous earth more readily ; hence, when expofed to the blow-pipe with this falt, it is refolved into a powder, with a momentary effervefcence. The microcofmic falt diffolves lime and argillaceous earth very well, but hardly the filiceous ; yet, as this is but in fmall quantity, by means of the former the latter is taken up though flowly. Finally, borax, which in the dry method, ftrongly attracts all the principles, diffolves their combinations more eafily than the other falts.

The

The fame kind of delay which the argillaceous and calcareous earths occafion in the action of fixed alkali, by covering the filiceous earth, does the clofe union of that earth with them occafion to acid menftrua ; fo that, without fome previous preparation with alkali, fcarcely any thing can be extricated, except the lime and the metallic part.

§ VII. *Cryftals allied to the Gems.*

Upon confidering what has been faid, I believe no one will deny that in a fyftem of natural hiftory the gems belong to the tribe of compound argillaceous fubftances ; but as nature operates by infenfible degrees, it will not be improper here to confider other cryftals which are nearly related to the gems ; for by increafing the proportion of filiceous earth a great number of fubftances, compofed of the fame materials, will appear, differing from them more or lefs.   To this clafs belongs a number of ftones, fuch as garnet, fchoerl, zeolith, and quartz ; the two former of thefe, examined in the fame way as the gems (§ v.), exhibit the fame principles, but in thofe the filiceous earth predominates over the argillaceous; yet is the connection of the principles fo clofe, that the garnet always ftrikes fire with fteel, and the fchoerl not unfrequently. Thefe are followed by the zeolith, the texture of which is fo lax that acids feparate its

H 4   conftituent

conftituent parts, without any other previous
preparation than a mechanical pulverization.
The zeolith very feldom ftrikes fire with
fteel, yet is fometimes found hard enough
for that purpofe : fuch is the white zeo-
lith of mount Moeffeberg in Weft Goth-
land, and the green in the gold mine at
Adelfors : it is alfo very feldom tranfparent.
The quartz forms as it were the extreme
link of the chain ; for this abounds fo much
with filiceous earth, as almoft to conceal
the other principles : if the analyfis be at-
tempted with a double quantity of mineral
alkali, it is extremely difficult to moderate
the fire fo as to prevent fufion ; the falt
muft therefore be reduced to $\frac{1}{8}$.

If the menftrua be afterwards employed
in the manner defcribed for the gems, very
little clay or lime is obtained. I am not
certain whether there be any mountain cryf-
tals entirely filiceous, which perhaps may be
the cafe. I have long fince declared, that I
did not difcover any argillaceous earth ; but
at the fame time I obferved that the ex-
periment was imperfect.

It will be proper to conclude, by efta-
blifhing the characters of the ftones which
have been accurately examined (for the be-
nefit of mineralogifts) ; and at the fame
time to explain their genefis and connec-
tions.

We fhall firft define thofe which be-
long to the clafs of argillacea ; concerning
which,

which, though the chief circumstances have been already mentioned, I think it fit to repeat them in a compendious way, and then go on to the silicea.

The Gem.

A small piece of this, exposed on charcoal to the blow-pipe, does not flow; but by a very long continued flame, the hyacinth and emerald, to which we may add the aqua-marinus and the cryfolith, are softened and rendered opake.

Fused with the mineral alkali in a filver spoon, no effervefcence is obferved, nor any diminution, except in the emerald, the aqua-marinus, and the cryfolith, which are as it were upon the confines of the fchoerls; thefe are refolved into a powder, but a refractory one, which revolves in the globule of falt, without any fenfible diminution.

It is diffolved, though flowly, by the microcofmic falt, without any commotion. Glafs is not tinged, unlefs by the red ruby, which colours it of a beautiful green: it remains nearly tranfparent with the reft: with the hyacinth and emerald it grows opake upon cooling.

With borax it difappears a little fooner. An addition of lime affifts the folution, which was firft obferved by the celebrated D. Quift, and agrees extremely well with its known compofition.

The

The acids, by long digeftion, extract a fmall portion of the lime and iron; but if the gem has been previoufly treated with alkali, they alfo take up the clay; fo that the filiceous earth alone remains undif-folved.

In general the gems confift of an argilla-ceous earth, which forms the greateft part; then filiceous earth; then lime; and, final-ly, iron varioufly modified: the propor-tions of each fpecies muft be determined by a great number of experiments. It alfo remains to be determined, whether the various colours of each fpecies occafions any diverfity; and whether the hexagonal or octaedral prifmatic form conftantly indicates any remarkable variety in the compofition.

The ruby is generally of an octaedral form; fometimes too, accidentally, fchoerla-ceous: analyfis has not yet determined the compofition of any prifmatic ruby.

The fapphire is fometimes found cryftal-lized like quartz; fometimes it bears the form of an oblique parallelopiped; fome-times, as authors relate, it is octaedral.

The topaz commonly affects either a cu-bic or parallelopiped form, in fuch a man-ner, however, that the figure is feldom com-plete, but the number of fides is augmented by the defect in the prifm itfelf, and par-ticularly in the margin of the plane ex-tremity.

The

The hyacinth alfo exhibits a tetragonal prifm, but terminated by a pyramid (tab. i. fig. 2).

The emerald is generally an hexagonal prifm, truncated at right angles.

No perfon devoted to the ftudy of mineralogy fhould forget of how little confequence external marks are, efpecially as ftones by triture become fhapelefs, or at leaft irregular. Science has much to expect from the analyfis of cryftals, both of the fame and different figures, although, before the compofition can be examined, they muft be artificially deprived of their natural form.

The fpecies of gems is ufed to be determined by the hardnefs ; and by that quality particularly, together with the clearnefs, has their goodnefs been eftimated. The fpinellus is particularly worthy of obfervation, which is not only powdered by the fapphire, but even by the topaz ; as alfo the cryfolith, which is broken down by the mountain cryftal, the hardnefs of which feems rather to be owing to the degree of exficcation than the proportion of ingredients. The analyfis of fpinellus, of cryfolith, and other varieties, will fometimes illuftrate the true connection ; otherwife, after the diamond, the firft degree of hardnefs belongs to the ruby, the fecond to fapphire, third to the topaz, next to which comes
the

the genuine hyacinth, and, fourth, the emerald.

Formerly colour was entirely confided in; but now neither can a red characterize the ruby, a blue the sapphire, a yellow the topaz, or a green the emerald.

The specific gravity varies so much, that from it nothing certain can be determined concerning the species; but the topaz is generally most weighty, from 3,460 to 4,560; the next is the ruby, from 3,180 to 4,240; then the sapphire, from 3,650 to 3,940; and, finally, the emerald, from 2,780 to 3,711; among the varieties of which last the crysolith is most ponderous.

The Garnet.

A small piece exposed to the flame flows without ebullition, sometimes into a green pellucid globule, sometimes into a black scoria.

With mineral alkali it resolves into a refractory powder so slowly, that scarce any effervescence is observed: when the iron predominates the mass grows brown.

With microcosmic salt it dissolves, without any appearance of bubbles, yielding a glass, which is green or blackish, if much iron be present.

With borax the same circumstances take place.

The acids extract scarce any thing more
than

than the lime and iron; but after preparation with alkali, they also take up the clay, which being separated the siliceous earth remains alone.

The siliceous earth forms the greatest part; next the argillaceous; the calcareous is in still smaller quantity.

The iron varies much; the pellucid crystals contain about 0,02, the opake and black sometimes so far as 0,2 : lead is seldom present. The crystals which contain tin, called zingraupen, are nearly allied to the garnets.

The form, when complete, is dodecaedral, consisting of equal rhombi; this may be conceived as an hexagonal prism, terminated at each end by three rhombi. It sometimes puts on the hyacinthine form, though but seldom complete, especially when loaded with tin : the varieties are manifold; the internal texture is laminated, though not conspicuously.

It yields in hardness to the topaz, but exceeds the mountain crystal.

The colour of pellucid garnet is red, sometimes more or less verging to yellow, sometimes to violet : that of the opake is yellow, red, or blackish.

It approaches nearest to the topaz in specific gravity; and, when copiously loaded with iron, scarcely exceeds it, being from 3,600 to 4,600.

The

The Schoerl.

A small piece exposed to the flame foams slightly, and grows soft, but can scarcely be collected into a globule, as is the case with the turmalin of Ceylon, which is akin to this, as also with the squamous schoerl, called horn-blend.

With the mineral alkali it resolves into a powder, with a slight and almost momentary effervescence.

With microcosmic salt it dissolves with a slight effervescence ; and on the addition of a greater quantity, the globule begins to grow opake.

With borax the case is the same ; but the globule remains clear, unless made blackish by a large quantity of iron.

By long digestion the acids extract the calcareous earth, the metallic part, and even a great quantity of the clay ; but by previous preparation with alkali, the more soluble parts separate from the siliceous earth.

The siliceous earth is in somewhat greater quantity than in the garnet ; the argillaceous is next in order ; last, the calcareous. The martial ingredient forms about 0,04 in the pellucid crystals ; in the opake, particularly the black, it sometimes amounts to 0,2.

Its crystalline form, when complete, is the same with that of the garnet, only the prism is more elongated ; but it is very seldom

dom

dom found perfect ; hence the defect of apices and prisms of a greater number of sides. The angular longitudinal excavations are doubtless the vestiges of crystalline spiculæ formed at the same time ; the hornblend is generally found concreted into squamous square lamellæ ; the texture is spathaceous, though not always conspicuous.

It scarcely exceeds the mountain crystal in hardness ; but the prismatic may often be cut by a knife ; the squamous always.

The colour of the translucid crystals is yellow or brown, but generally green : the opake black or green.

It is nearly equal in specific gravity to the garnet, between 3,000 and 4,000 ; the clear crystals are generally lighter.

The Zeolith.

A small piece exposed to the flame swells up like borax, with the greater vehemence in proportion as it is more crystalline ; it finally goes off in a spumous scoria, and can very seldom be brought into a globule ; a few varieties of it shew a momentary expansion of volume, and that without any ebullition.

With the microcosmic salt it swells in dissolving, but slowly, and the globule remains clear.

7   With

With borax it diſſolves in the ſame man-
ner.

The acids extract every thing that is ſo-
luble, without previous preparation with
alkali, nay ſometimes they reſolve it into
a jelly.

In this too the ſiliceous earth is more
abundant than the argillaceous; the calca-
reous makes the ſmalleſt part; the iron
ſcarcely exceeds 0,01.

The form of the cryſtals is ſeldom priſ-
matic; generally an imperfect pyramid;
many diverge from the ſame point, with
broad extremities, and often coaleſce into
ſmall ſpheres.

Its hardneſs is ſeldom ſo great as to ſtrike
fire with flint; generally it will not even
cut glaſs.

The colour white and red, ſometimes
green, very ſeldom tranſparent.

It is not of great ſpecific gravity, ſcarce
exceeding 2,100.

From what has been ſaid it plainly ap-
pears, that the garnet, the ſchoerl, and
the zeolith, are united in the ſame degree
of affinity as the ruby, the ſapphire, the
topaz, the hyacinth, and the emerald; yet
in ſyſtematic arrangement the three firſt
named are placed not only under diffe-
rent genera, but often under different or-
ders. The hardneſs encreaſes in proportion
to the clay: from the zeolith, through
the ſchoerl, to the garnet, we may follow
the

the natural chain, by defcending through the faxum trapp. to the marga;—in this there occurs no more than a mechanical mixture. Every clay which I have had an opportunity of examining contains filiceous particles, finer or coarfer, mixed with it, but always exceeding the weight of half the mafs, frequently amounting to 0,7, nay to 0,8; it is generally alfo mixed with iron, from 0,03 to 0,20. Let us now fuppofe the accefs of a little calcareous earth, and we fhall have the marga, which is difcovered by an effervefcence in acids, although the calcareous earth does not exceed 0,02. In the faxum trapp. analyfis difcovers the fame principles, not feparate, as in the former cafe, but united, and that not merely by induration, but by a fpecies of rude cryftallization; for the microfcope difcovers the texture to be fpiculated or granulated: fuppofe this to be reckoned among the faxa, the diftinguifhing property of which is to exhibit particles of different natures, diftinguifhable by the eye; it will at leaft be found the moft fubtile of mechanical compofitions, and conftituting a link of the chain which unites the faxa with thofe which, although compounded, are yet fo homogeneous and concreted, by the attraction of their parts, that the eye, even affifted by the glafs, cannot diftinguifh their conftituent parts; as all the integrant parts contain the fame proximate principles, and in the

fame proportion as the whole does. To this belong the gems, the garnet, the fchoerl, the zeolith, and other derivative earths, which Mr. Cronftedt confiders as primitive.

I leave it to be determined whether cryf-tals may be formed without the help of any other menftruum than water :—to me it appears very probable that any fluid vehicle, even though not a folvent, may be fufficient for this purpofe, provided the minute atoms are fo fufpended in it that they may freely obey the laws of their mutual attraction. The very minute molecules exert attractions proportioned to the amplitude of their fur-faces ; a force which is deficient in larger particles. More or lefs of water alfo feems to enter the texture of ftony cryftals, al-though, by age and exficcation, this is gene-rally expelled. The foaming of the zeolith in the fire is owing to moifture going off in the form of vapour, and no doubt it is a fmaller quantity of this that occafions the leffer ebullition in the fchoerl, ftill lefs in the garnet, while there occurs none at all in the gems.

The petrofilices alfo contain filiceous, argillaceous, and calcareous earth, intimate-ly united.

On the other hand we may fhew the pro-grefs of gems, through the mountain cryf-tals to the pure flints. The cleareft cryf-tals of quartz, which come from Jetland, treated with $\frac{1}{4}$ of mineral alkali (§ v.)

afterwards

afterwards yielded to acids 0,06 of clay, and 0,01 of calcareous earth; so that the same principles are found as before. If any one suspects that the whole of the insoluble residuum, by successive preparation with alkali, might in like manner be resolved into argillaceous and calcareous earth, I can inform him that I have made the attempt in vain.

§ VIII. *Of the Diamond.*

As the diamond is confessedly the chief of the gems, commonly so called, I have in the preceding pages only mentioned such circumstances concerning it as serve to evince that it differs essentially from the rest: I am far from being able to illustrate this difference further by a perfect analysis, yet it may not perhaps be altogether useless to mention so much as I have been able to discover. This operation is extremely difficult, partly on account of the extravagant price, which is required for such quantities as are necessary to make experiments which can be relied on, partly on account of the nature of the stone itself:—in order therefore to smooth the way, by removing obstacles, for those whom curiosity may invite to the examination of this gem, and whom circumstances permit to proceed more easily than I have been able to do, I shall relate such circumstances as I have discovered.

The

The diamond differs from the ruby and the other gems (as has been said before) by a degree of hardness unknown in any other production of nature, and particularly by its fugacity in a moderate heat (such as is sufficient to melt silver) or rather by its flow deflagration; for when made completely of a white heat it not only sensibly diminishes in bulk, but is surrounded by a little flame or cloud: but, so far as I know, the cubic or schoerl-formed diamonds have not yet been duly exposed to fire; so that it remains to be discovered experimentally whether those also entirely fly off, and if not they must lose the name of diamonds.

The diamond, urged by a very intense heat, contracts a sort of soot upon its surface.

We now proceed to examine its habits with respect to menstrua.

(A) The powder fit for these experiments is to be had by rubbing two diamonds, entirely deprived of their external covering, against one another (for it is yet doubtful whether the cortical part be entirely of the same nature with the nucleus). Such a pulverization requires larger diamonds than it was in my power to procure upon this occasion, I was therefore obliged to content myself with the examination of the powder which is for sale. It is reported of the diamond, that it yields a powder nearly black; which is certainly true of the

7   powder

powder that is fold; but this colour is not to be confidered as natural, as the blacknefs can be eafily extracted by acids, the particles remaining white; fo that the colour muft be owing either to the inftruments employ-ed, or to the cortical part of the ftone. Yet it may happen that black diamonds, which cannot be converted to other ufes, may be pulverized; and no doubt in this cafe the colour will be more fixed.

(B) This powder, when well depurated by aqua regia, eludes the force of other acids; yet with the vitriolic acid it exhibits a curious phænomenon. This menftruum, poured upon the powder, and evaporated to a fmall quantity, grows black, and depofits black pellicles, which it is very difficult to dry; thefe pellicles take fire upon the ap-proach of flame, and are almoft entirely con-fumed, at leaft they leave fo minute a re-fiduum that the nature of it could not be examined. It is a queftion whether this is the veftige of a footy matter: I could not obferve the fmoke of phlogifticated vitriolic acid proceeding from the fire.

(c) I treated the depurated powder with three times its quantity of mineral alkali, in the manner above defcribed (§ v.): after remaining three hours in the fire the pow-der did not fhew a fenfible cohefion; how-ever I extracted the foluble part by marine acid, and then attempted a precipitation with vegetable alkali; and in fact a light,

I 3   whitifh,

whitifh, fpongy, fubftance was thrown
down, which diffolved in all the mineral
acids, but with the vitriolic produced nei-
ther fpathum ponderofum, nor gypfum,
nor Epfom falt, nor perfect alum; it con-
creted indeed into cryftals, but of an irre-
gular form, eafily foluble in water, which
liquefied by the blow-pipe, and were then
abforbed by the charcoal; they were of an
acid yet auftere tafte.

(D) I again treated the undiffolved pow-
der mentioned in c with double its quan-
tity of mineral alkali; this concreted into
a firm mafs, from whence it appeared that
its nature was at length fenfibly changed.
I elixated with marine acid, and by means
of vegetable alkali precipitated a portion of
earth fimilar to that obtained in the former
operation; but the infoluble refiduum ftill
floated on microcofmic falt and borax in
fufion, as related in § 11. A very fmall
portion of it entered the mineral alkali
with effervefcence, but was no further dif-
folved; befides, the quantity was too fmall
to be fubjected to further experiment.

(F) Thefe experiments, although they
fhew that the analyfis of the diamond is
difficult, fhew alfo that it is not impoffible.
That there is prefent a portion of filiceous
earth, but very clofely united to the other
principles, feems to be indicated by the
flow action of the alkali: the precipitates
fhew that there is an earth foluble in acids,
                                        the

the nature of which remains to be difco-
vered by employing a larger quantity. The
deflagration, the foot, and the black pellicles,
fhew the prefence of an inflammable matter,
unlefs we rather fuppofe them owing to he-
terogeneous matters adhering to the powder
for fale.

(G) As the microcofmic falt feems to
diffolve fomewhat of the diamond by long
fufion upon charcoal, I put feveral globules
much loaded with it into diftilled water,
hoping that if it contained any, this, united
with the phofphoric acid, would be diffolved
in the water, and might then be feparated
by fixed alkali : nor was I entirely difap-
pointed ; the globules fell to pieces, the in-
foluble part of the powder fell to the bot-
tom, the reft was diffolved by the water,
and again feparated by an alkali, but it fell
very fparingly and flowly.

Thefe circumftances will perhaps give
fome light to thofe who are in poffeffion of
a larger quantity of adamantine materials, by
which they may be enabled to complete the
analyfis of this precious ftone, which, on
account of its clearnefs, its hardnefs, and
fplendor, is fo much valued ; although by a
gentle heat it is totally convertible into va-
pour in the fpace of a few hours ; while
the ruby and the other gems fuftain the
fame operation without damage.

I 4   D I S S E R-

DISSERTATION XVI.

OF

THE EARTH OF THE

TURMALIN STONE.

---

§ 1.

THE electrical virtue of this earth has been the admiration of philoso- phers, during the whole of the prefent cen- tury; and many years fince I attempted to reduce its peculiar effects to conftant laws : but no one, fo far as I know, has yet un- dertaken the analyfis of thefe ftones, being prevented by their fcarcity and dearnefs. My illuftrious friend Born removed this ob- ftacle for me, by fending me, in 1778, a par- cel which was got at Tyrol, and at the fame time requefting me to inveftigate their pri- mary principles. Some time after, that ac-

<div align="right">complifhed</div>

complifhed botanift, Mr. Thunberg, de-
monftrator in the garden at Upfal, on his
return from Java and Japan, kindly brought
me fome turmalins, which he himfelf had
got in Ceylon, rude, and unchanged by art.
I have therefore been fortunate enough,
through the kindnefs of thefe gentlemen, to
be able to compare the form and compofi-
tion of thefe the rareft production of the
mineral kingdom, produced in the moft
diftant quarters of the world. In this place
I fhall only confider thofe circumftances
which illuftrate the external form, the in-
ternal ftructure, and the component parts ;
deferring to another opportunity the con-
fideration of their electric virtues, which
fhall be confidered by themfelves.

§ II. *Vifible Qualities of the Turmalin Stone.*

Heretofore the turmalins were brought
either from Ceylon or America, and no one
fo much as fufpected that fuch were to be
found in Europe ; but two years fince, that
indefatigable examinator of the Tyrol moun-
tains, Mr. Muller, difcovered cryftals of this
kind, at Zillerthal, far fuperior, both in
beauty and magnitude, to any that had been
ever brought, either from Afia or America ;
therefore we may confider them as fepa-
rated into three claffes, according to the
places where they are found ; and we fhall
                                    begin

begin with thofe of the new world, which differ in certain properties from the reft.

(A) The turmalin of Brazil is frequently fomewhat heavier than the others, being, with refpect to diftilled water, from 3,075 to 3,180 : they differ in colour ; and I have feen them blue, red, and of a pellucid yellow, but generally they are green.

When rough they are of a columnar form, more or lefs regular ; but frequently are of a trigonal form, confifting of nine fides, as has been already defcribed and delineated. The apices are often deficient, and their fracture is glaffy ; but fometimes, if preferved and examined, they are found low, and compofed of three planes, as is explained in the Tract on the Formation of Cryftals (§ 11. E, and tab. i. fig. 3.)

The prifms, expofed laterally to the light, are almoft always pellucid ; but when viewed in the direction of the axis a wonderful opacity prevails, and that even in the tranfverfe fection, although it be very thin : whether this holds with refpect to the thinneft lamina is not yet eftablifhed ; perhaps this, like the following, when fufficiently diminifhed in thicknefs, will tranfmit the rays of light.

They yield in hardnefs to the quartz, and even to the other turmalins ; yet they cut glafs, and ftrike fire (though not eafily) with fteel.

(B) The turmalin of Ceylon varies a little in fpecific gravity between 3,062 and 3,295 ;
thefe

thefe feldom come to Europe unwrought : I
was therefore much pleafed to get thofe which
I mentioned. The columns of three of them
were whole, about three lines in length,
and two in breadth : three of the fides are
broad, feparated by a pair very narrow, fo
that at firft they appear trigonal ; two of
thefe prifms have apices, the folid angles of
which are very obtufe, and formed of three
irregular pentagons. All thefe circumftan-
ces agree perfectly with what has been faid
in A, of the turmalin of Brazil, and are made
abundantly evident by tab. i. fig. 3. but
the prifms are found furrowed longitudi-
nally, a circumftance which plainly points
out that other fpiculæ had cryftallized at
the fame time, and in contact with them.
Marks of this kind frequently appear upon
the furface of cryftals ; and the longitudi-
nal furrows above mentioned are very com-
mon, particularly in the fchoerls and tur-
malins of Brazil.

The colour of the cryftals is brown, and
not unfrequently almoft black ; but fome-
times more dilute, always however more or
lefs inclined to yellow ; which may be more
eafily obferved by placing the column tranf-
verfely between a ftrong light and the eye.
A tranfverfe fection, half a line in thick-
nefs, ftill appears opake, when expofed to
the day-light, although the flame of a candle
renders it femi-tranfparent and brown ; but
                                              when

when made thinner, so far as $\frac{1}{10}$ of a line, it becomes pervious to the day-light.

I have also got shapeless pieces of nearly the bulk of a walnut, their subtile parts spathaceous, black, and opake; in these the electrical power is much weaker.

They nearly agree in hardness with quartz. The electrical property of these stones seems to be unknown in Ceylon; and although, beyond doubt, the name *turmalin* is a word of the Ceylon language, yet, under the same name, Dr. Thunberg got stones of various colours, and various genera, of which, among eight varieties, not one acquired the electric quality by heat, altho' I frequently made the experiment. Dr. Thunberg also informed me, that, in the genuine language of the country, the word signifies black crystals; that they are little esteemed, and are pounded and formed into globules to serve the purpose of buttons.

(c) The turmalin of Tyrol has been so exactly described by the learned discoverer, with respect to external appearance, that nothing can be added; but, for the sake of comparison, it will be proper to repeat the principal circumstances.

The specific gravity is 3,050, that is less than any of the preceding.

The crystals are sometimes three inches in length, and exceed five lines in diameter, partly loosely dispersed among, partly firmly united to, a steatite, mixed with particles
of

of mica, not unlike the olla Jetlandica. What the matrix of the other turmalins may be, is yet unknown ; but that of the Tyrol tur-malin form either veins or nuclei in granite.

The figure is prifmatic, confifting of nine fides, fometimes terminated by three penta-gons like that of Ceylon, but in general the apices are wanting : fometimes, however, though very feldom, the pyramids are found very much acuminated, with nine fides ; therefore, in general, all the known turma-lins agree in form ; but, fo far as I know, the complete fchoerl form (tab. i. fig. 1.) has not yet been feen among them by any one ; — a form which, even among the fchoerls themfelves, is extremely rare.

Such of the Tyrol cryftals as I have exa-mined are without the longitudinal fulci ; but the furface, when accurately examined, fhews a flight afperity, owing perhaps to the fpicular form of the furrounding ma-trix ; but the tranfverfe chinks, generally ob-fcure, are found in thefe and the preceding, as well as in the fchoerls.

The colour occafioned by reflex light is footy, or of a brownifh black, but that by refracted light of an obfcure yellow ; a thin tranfverfe fection appears opake, but when the thicknefs is fufficiently diminifhed, it at length tranfmits green rays, as the cele-brated Muller firft obferved, and as I have myfelf feen, the account is true. The Ceylon and Tyrol turmalin therefore agree

in

in this, that by extreme tenuity a paffage is made for the light ; but they differ with re-fpect to the rays, which are tranfmitted.

(D) Many years fince I obferved that a variety of the fchoerl, black, opake, of a complete figure, which came from Umæan Lapland, by a due degree of heat acquired electrical properties. Upon multiplying experiments I found the fame thing to take place in feveral fchoerls of Sweden, both nonagonal and fpicular, of very irregular forms—thefe were all totally opake ; and heretofore I have not obferved that property to take place in any that was pellucid.— How this electricity may be excited, and its nature explored, I defer to another place, where this matter fhall be exprefsly confidered.

§ III. *Habits of the Turmalin expofed to the Blow-pipe.*

(A) A fmall piece, the fize of a grain of muftard, expofed upon charcoal to the apex of the flame, quickly grows red, and that without any decrepitation or other vifible change : but if the action of the flame is continued for fome minutes, it foon grows white, foams almoft like borax, and, upon continuing the fire, is reduced to a globule ; a larger piece fufes with difficulty, but yields an inflated fpongy white fcoria.

10   This

This is the cafe with the turmalin of Tyrol and Ceylon when cryftallized; but the black and fhapelefs pieces fwell but little, and the marks of fcorification which appear on the furface are brown, not white; that of Brazil cannot be formed into a globule, but exhibits a puftulous fcoria.

(B) The microcofmic falt, fufed upon the charcoal, attacks a fmall quantity of turmalin with a flight effervefcence, which is yet foon at an end; and there remains a fmall corpufcule, almoft tranfparent, and therefore fcarce perceptible, until after the globule grows cold: this refiduum is diffolved with great difficulty, but the reft of the vitreous mafs furrounding it is found clear and tranfparent, which grows green on a farther addition while hot, and milky on cooling, chiefly occafioned by the undiffolved particles. All the varieties in this refpect are the fame, except that the black and opake occafion a brown colour.

(c) Borax takes up the turmalin almoft in the fame way, but generates heat more diftinctly, and diffolves the ftone more powerfully, fo that it hardly contracts a perfect opacity, except the black turmalin, which added in fmall quantity changes the tranfparency to a yellow brown, but in larger quantity to a black opacity.

(D) Mineral alkali takes up the turmalin in fufion with effervefcence, but a lefs confpicuous one than that excited by quartz: when

when a fmall portion of the ftone is added, it
is broken down into a powder, but is imper-
fectly diffolved : the black opake turmalin
makes the globule brown.

(E) The turmalin approaches next to the
fchoerl in the habit juft defcribed ; the lat-
ter is, however, more completely diffolved,
and with more evident ebullition, by the
microcofmic falt, and alfo effervefces more
vehemently with mineral alkali.

§ IV. *Habitudes of the Turmalin with Acids.*

(A) Three times the weight of concen-
trated vitriolic acid, poured on 100 lb. of
fubtile powder of turmalin, feparated by elu-
triation, and expofed to diftillation in a fmall
retort until the bottom of the glafs grows
red hot, yields a refiduum, which being
boiled in diftilled water, collected, dried,
and weighed, is found to have loft about
16 lb. The three known varieties are, in
this refpect, fcarce found to differ a pound
or two.

The water which has extracted the folu-
ble part, with a lixivium of burned blood
yields Pruffian blue ; and, the iron being
thus precipitated, on addition of fixed al-
kali a white powder is thrown down,
which, with vitriolic acid, forms gypfum ;
which may again be decompofed by acid of
fugar : the acid has therefore been only
loaded with iron and lime.

The

The acid collected in the receiver is found to be purely vitriolic.

The elixated refiduum, examined by the blow-pipe, fwells and fhews almoft the fame habits as the crude turmalin.

(B) The nitrous and marine acids alfo extract iron and lime ; but in other refpects have no greater effect than the vitriolic, for the refiduum ftill remains compound ; the furface therefore is not fufficiently encreafed by the mechanical pulverization, fo that the menftrua may be able to feparate the component parts : however, the method which I followed in decompofing the gems fucceeds in this cafe extremely well.

§ v. *Proximate Principles of Turmalin.*

(A) I treated a very fubtile powder of turmalin in the fame manner as the gems, with this difference, that I employed an equal quantity of mineral alkali, fpontaneoufly calcined, and kept the mafs ignited only for an hour and a half.

(B) Upon cooling, the mixture is found colliquated, its furface convex, tuberculated, of the colour of wax, but internally fpongy, and of a green colour, which is of a deeper hue, as it approaches the bottom, to which it adheres. The mafs, when fufficiently loofened, is covered at the bottom with a black cruft, which is carefully feparated and weighed.

VOL. II.   K   (c) The

(c) The reſt of the procefs was conduct-
ed as defcribed on the Earth of Gems, ғ
and ɴ; it would therefore be fuperfluous
to defcribe it again. Thefe operations yield-
ed the following concluſions concerning
the quality and proportions of the confti-
tuent parts in an affay hundred; *viz.*

The turmalin of Tyrol.

argillaceous earth	-	-	42
filiceous earth	-	-	40
calcareous earth	-	-	12
iron	-	-	6

Turmalin of Ceylon.

argillaceous earth	-	-	39
filiceous earth	-	-	37
calcareous earth	-	-	15
iron	-	-	9

Turmalin of Brazil.

argillaceous earth	-	-	50
filiceous earth	-	-	34
calcareous earth	-	-	11
iron	-	-	5

(D) By argillaceous and filiceous earths,
I here underftand thofe earths freed from
all heterogeneous matter; but the calcareous
earth appears to be nearly faturated with
aerial acid, as otherwife a greater defect is
obferved than can be fuppofed in an accurate
operation. That no effervefcence takes place
with acids is eafily accounted for, when we
                                                confider

confider that only a very minute portion of calcareous earth adheres fo very clofely to the other conftituent parts, that it has fufficient hardnefs to ftrike fire with fteel : the iron is dephlogifticated, and the crude turmalin does not fhew the leaft fign of detonation with nitre.

As to the proportions of the conftituent principles, I have fet down fuch as experiments fuggefted; but it is neceffary to take the medium of a number of experiments, as nature does not obferve fo exact a proportion in the admixture of the principles of bodies, but that fometimes there may be fome hundredths too much or too little; befides, a feries of operations (notwithftanding the greateft poffible accuracy) will fometimes add a little weight, or fometimes diminifh, which is particularly fenfible when very fmall quantities are ufed. Thus, in the prefent inftance, I have not yet been able to fubject to experiment more than a few affay pounds : in thefe experiments I conftantly found the fame ingredients, but the proportion of them required fome correction. The difference of habits difcovered by the blow-pipe manifefted fome difference between the Tyrol and Ceylon turmalin ; but whether the above proportions be exact, remains further to be examined.

(F) That water enters the compofition may be gathered from their undergoing the

fame

fame ebullition in fufion as the zeolith does, which certainly contains water; but the quantity of matter to be examined only permitted me to make one trial with this view. I kept 100 lb. of Tyrol turmalin grofsly powdered for half an hour in an obfcure red heat; but upon cooling found no difference in weight, nor did I expect any, as a white heat is neceffary to fufion: I therefore encreafed the fire to a fufficient degree, but the fragments of turmalin were agglutinated to the crucible, nay, had entered into a fort of union with it; I therefore made the experiment in another, which was tedious and troublefome:—I took 25 affay pounds of fragments of turmalin, each of which I feparately reduced to white fcoriæ by the blow-pipe, but I did not find that the weight was fenfibly diminifhed; a proof that there is either no water at all, or only a very fmall quantity.

§ VI. *The Place belonging to the Turmalin in a Syftem of Mineralogy.*

Being acquainted with the nature and proportion of the earthy principles which enter into the compofition of the turmalin, we cannot hefitate to place it among the argillaceous fpecies, fince the chief part of it is conftituted by this earth, which, even when it is prefent in fmaller proportion,

communicates

communicates its peculiar properties to the whole mafs.

In the gems we find the fame principles, and clay in greater proportion than any other earth : the turmalin can fcarce be referred to this clafs, becaufe its ftructure is fo much loofer.

The phænomena it exhibits, when treated with the blow-pipe, approach nearly to thofe of zeolith; but of this filiceous earth conftitutes the principal part : and the conftituent principles cohere fo weakly that acids are capable of extracting them without any previous treatment with fixed alkali, and the heat of diftillation of expelling moft of the water. It is more clofely allied to fchoerl; for the turmalin not only refembles this in the form of its cryftals, and the phænomena it prefents, both with heat and folvents, but alfo fometimes in being electrical, a property which fhall be particularly examined in the fequel; it however differs in containing more filiceous earth, and fome other circumftances before noticed (§ III. E).

DISSERTATION XVII.

OF

THE FULMINATING

CALX of GOLD.

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§ 1. *Historical Introduction.*

ALTHOUGH the wonderful fulmi-
nating property of gold was known
at leaft in the 15th century, it has not
yet been examined by philofophers fo as
to determine with certainty the caufe of
the prodigious noife and ftupendous ex-
plofive force; yet in this explofion there
occur phænomena highly worthy of at-
tention—phænomena which not only in-
dicate very fingular properties, but are of

<div align="right">fuch</div>

fuch a kind that the caufes of them, well underftood, muft certainly throw great light upon the theory of chemiftry. The following experiments, which are partly new, and partly fuch as have been defcribed by others, but carefully revifed and corrected, will I hope tend to illuftrate the fubject. But before we enter upon them it will be proper briefly to relate the attempts of others, who have made this bufinefs their particular ftudy.

Whether or not the ancient alchemifts were acquainted with the fulminating property of gold, we are ignorant ; their arcana being involved in an enigmatic and obfcure ftile. Bafil Valentine is perhaps the firft who has clearly defcribed the method of communicating this property to gold : he directs the metal to be diffolved in aqua regia made with fal ammoniac, and then precipitated by vegetable alkali, to be twelve times wafhed with water, and finally dried in the open air, where the fun's rays cannot reach the powder ; he forbids it to be dried over a fire, as it explodes with a gentle heat, and flies off with inconceivable violence ; but he has not diftinguifhed this calx by any peculiar name.

Many chemifts afterwards performed this operation, but here and there we obferve fome fmall difference.—O. Crollius calls it *aurum volatile*, and is fcarce willing to have it dried, even though carefully, and in bal-

K 4   neo

neo maris ; but above all forbids the ftirring it with an iron fpatula. J. Beguin added the epithet *fulminating*, which has been fince generally adopted ; although we fome-times meet with the terms *fclopetans* and *ceraunochryfon*.

The neceffity of employing volatile alkali in this operation was but little regarded until the prefent century ; for Hellot tells us, from Groffe, that gold diffolved in a mixture of nitrous and marine acid, fulminates better when the volatile is ufed than when the vegetable fixed alkali is employed ; but that if the menftruum be made with fal ammoniac, the latter precipitate is beft. Zwelf calls the gold precipitated by fixed alkali, without the fulminating property, *aurum mutum*. Ettmuller and Hoffman found that precipitated by volatile alkali always fulminating.

Becher found the fulminating powder, when well wafhed, heavier than the gold employed by $\frac{1}{5}$; Lemery by $\frac{1}{4}$; and Jungken by $\frac{1}{3}$: it is doubtful whether Barner ever made the experiment, as he affirms that in order to produce the beft effect it fhould not be wafhed with water (compare § x). Many alfo, after him, have thought that by boiling in water the fulminating property is deftroyed, or at leaft diminifhed ; the celebrated Beaumé was the firft who detected that error.

That

That water loaded with fixed alkali when boiling takes away all the explosive power, is afferted, if I miftake not, by all the moderns, following the author of Homer's Golden Chain. Kunckel found this property deftroyed by vitriolic acid. Rolfincius, and others, contend that marine acid has the fame effect; and Mr. Spielman extends that faculty to all the acids, even to vinegar: yet Caffius relates that aurum fulminans exploded moft violently when marine acid dulcified was diftilling from it. Bafil Valentine attempted, not without fuccefs, to fubdue the fulminating property by means of fulphur.

A fingle fcruple of aurum fulminans explodes, as Crollius afferts, with more force than half a pound of gun-powder, and propagates its action downwards; yet H. F. Teykmeyer frequently fhewed in his lectures that it would throw a florin upwards above fix ells; and the fame effect had been obferved by many others before him.

A great number of experiments were made before the Royal Society at London, in order to determine the comparative forces of thefe two powders :—equal parts of gunpowder and of aurum fulminans were included in iron globes, which were placed among burning coals; thofe which contained the former were burft with violence, while the other remained perfectly filent. But if the globe containing the gun-powder

did

did not exceed the bignefs of a pea, the globe remained unhurt, although the contents had been inflamed.

Many unfortunate accidents however fhew that the greateſt caution is neceſſary in handling aurum fulminans: Orſchal relates, that this powder, ground in a jaſper mortar, had by its exploſion burſt the mortar into a thouſand pieces: the celebrated Dr. Lewis gives an inſtance of the ſame in England; nay, Dr. Birch tells us that by an exploſion of this kind doors and windows had been violently torn to pieces: but Mr. Macquer gives a very melancholy detail of a misfortune which happened in his own preſence:—a perſon of 22 had put ſome aurum fulminans into a phial, but unfortunately did not obſerve that a few particles adhered to the neck; upon ſhutting it therefore, as is uſual, by twiſting the glaſs ſtopper, the few particles exploded with ſuch force as to throw the young man among the furnaces of the laboratory, with the loſs of both his eyes, occaſioned by the ſplinters of the glaſs.

The ſentiments of chemiſts concerning the cauſe of the fulmination differ very much; the opinions of thoſe who ſpeak in words ſo obſcure that it is ſcarce poſſible to reduce them to ſenſe, we ſhall omit; the reſt may be divided into four claſſes, ſome aſcribing it to an aerial, ſome to a ſaline, ſome to a ſulphureous principle, and finally,

there

there are others who fuppofe it to depend upon feveral of thefe united.

F. Hoffman attributes it to humidity and an elaftic vapour dilated by heat ; but the celebrated Dr. Black affirms it to be owing to fixed air copioufly and fuddenly fet at liberty. A. Peterman afferts this power to depend upon the union of the folar principles with nitre ; but others, and indeed the moft of the moderns, fubftitute a fpecies of nitre totally volatile, which is commonly called *nitrum flammans*. Caffius fpeaks of fulphureous particles of gold which are difcharged from the bond of falts, as being fubftances of an oppofite nature, by means of the fire ; and, upon getting loofe, give as violent a concuffion to the air, as fulphur and nitre in common gun-powder ; but very lately M. Beaumé propofes as the caufe, a nitrous fulphur deflagrating violently ; and fupports this opinion with many fpecious arguments. Notwithftanding all thefe explanations, many philofophers are ftill of opinion, that the phænomenon is not yet accounted for : fuch are Boerhaave, Macquer, Spielman, and others.

If in our days a certain fragor vibergenfis were neceffary, a very violent one might be beft obtained by means of this calx of gold ; for no fubftance hitherto known explodes with a louder noife. Dr. Lewis compares the report occafioned by gun-powder to the found of a long and lax cord ; and that

of

of aurum fulminans, to that of a short and tense one. But in mines it cannot be substituted for gun-powder, as, when it is close shut up, it is reduced without noise or violence, as we have seen before; besides, this powder must be fired by heat, and not by sparks.

The celebrated Stahl says, that aurum fulminans, treated with sulphur, as hereafter described, is used as a pigment by goldsmiths and enamellers. Doffie mentions this as a valuable secret.

Formerly, three or four grains of this powder were given as a diaphoretic of extraordinary power, as we are told by Crollius and Beguin. Rolfincius relates an example of its cathartic virtue : his words are these, *Illustris regiæ Suecicæ militiæ generalis Pannerius* (doubtless *Banner*) *gravissimo colico dolore infestatus, clysteribus aliquot officium non facientibus, habuit melius, commota alvo, assumptis auri fulminantis granis 6 in cochleari pleno vini Malvatici.*

§ 11. *Preparation of Aurum Fulminans.*

This powder may be prepared in two different ways ; for either the gold is dissolved in a menstruum composed of nitrous acid and sal ammoniac, and the solution precipitated by a fixed alkali, or the solution is performed by aqua regis made without sal ammoniac (which may be done in various

rious ways) and the precipitation effect-
ed by volatile alkali. Aqua regis without
fal ammoniac may be prepared by mere
mixture of nitrous and marine acid, or by
nitre diffolved in marine acid; or, finally,
by fea-falt diffolved in nitrous acid. It is
obvious, that inftead of nitre or fea-falt,
other falts containing thefe acids may be
employed. *Menftruum fine ftrepitu* was a
name formerly given to a liquor confifting
of a little water with nitre, fea-falt, and
alum, in which gold-leaf was diffolved by
triture; in this cafe the acid of the alum
expels the other acids, which therefore, by
their union, form common aqua regia.

By whatever method the gold be dif-
folved and precipitated (provided the vola-
tile alkali is prefent, either in the menftru-
um or the precipitant) a yellow precipitate
is obtained, which, when well wafhed in
water, and cautioufly dried, is commonly
called aurum fulminans. The weight of the
calx, well wafhed and dried, exceeds that of
the gold employed, by about $\frac{1}{3}$.

The diffolved gold is more readily pre-
cipitated by volatile than by fixed alkali.

§ III. *Properties of the fulminating Calx
of Gold.*

The phænomenon which has chiefly ren-
dered this powder famous, and has given
occafion to the name, is the prodigious noife
occafioned

occafioned by the explofion of a few grains
expofed to heat in a metal fpoon, either
over a candle, coals, or a red hot iron; or
by any other means fufficiently heated.
How this phænomenon takes place, we
fhall fee hereafter.

(A) A degree of heat between 120° and
300°, the degrees at which the nitrous and
vitriolic acids boil, is fufficient for this pur-
pofe; but whether the folar rays, without
concentration, can produce the fame effect, as
fome perfons affert, I have not yet been able
to determine; but am inclined to doubt of
their poffeffing fuch efficacy, unlefs the au-
rum fulminans be extremely well prepared;
but if the mafs be infpected juft as it is
about to explode, in the very inftant pre-
ceding the explofion no other change is ob-
ferved than its colour verging to black, up-
on which it inftantly is difperfed with an
obfcure flafh, and a wonderfully acute found:
the fame effect is obferved whether the
powder be furrounded by common air, or
aerial acid.

(B) By fimple triture, or percuffion alone,
this powder is inflamed, and explodes with
great violence, whence melancholy acci-
dents have fometimes happened; but every
fort of aurum fulminans is not fufceptible
of explofion by thefe means. By boiling in
pure water, or (which is better) in an alka-
line lixivium, or (which is beft of all) by a
due degree of calcination, it is rendered fo

5   prone

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prone to inflammation, that by the electric
spark, nay often by the smallest agitation
with a piece of paper, it explodes; the
common aurum fulminans is also exploded
by the electrical shock.

(c) A portion weighing from 10 to 12
grains of aurum fulminans, exploded on a
metal plate, perforates and lacerates it; a
smaller quantity forms a cavity in the plate;
and a still smaller only scratches the sur-
face; an effect which is never produced by
gun-powder, though in much larger quan-
tity.

(d) A weight laid upon the powder is
thrown upwards in the moment of explo-
sion; and if it be of silver, it is found
gilded with a yellowish spot. In the same
way is marked the support, if it be made of
silver or copper.

Besides, a large grain, advanced near to the
side of the flame of a candle, blows it out
with violent noise; and a few ounces ex-
ploding together, by incautious drying, has
been known to shatter the doors and win-
dows of the apartment: hence it is evi-
dent, that aurum fulminans exerts its force
in all directions; yet it cannot be denied,
that it strikes bodies with which it is in
contact more violently than those which are
at a small distance, though in its vicinity:
thus, if a small portion of it explodes in a
paper box, it lacerates only the bottom,
unless the top be pressed down close, in
<div align="right">which</div>

which cafe it perforates both the top and bottom.

(E) When carefully and gradually exploded in a glafs phial or a paper box, it leaves a purple foot, in which are found many particles of fhining gold; nay, if the quantity exploded be large, feveral grains remain totally unchanged; for it is only the ftratum next to the heat which is inflamed, as may be fhewn by an eafy experiment, namely, if the fulmination be performed over a large furface of burning coals; for in that cafe a number of decrepitations will be heard, occafioned by grains of the aurum fulminans difperfed in a perfect ftate by the explofion of the inferior ftrata.

(F) When moift, it does not explode all at once, but each grain, in order as it becomes dry, decrepitates in a manner fimilar to common falt.

(G) In glafs veffels clofed, or with their mouths immerfed in water to prevent breaking, a moderate quantity explodes indeed, but with a very weak noife, fo as fcarcely to be perceived; but in the moment of explofion, an elaftic fluid breaks forth, which, when cool, occupies about feven inches, if half a drachm of the powder has been ufed: this air extinguifhes flame, deftroys animal life, rejects pure water, and does not even precipitate that which contains lime in folution.

(H) In

(h) In metallic veffels of fufficient ftrength and perfectly clofed, aurum fulminans, expofed to heat, is reduced filently, and without any marks of violence : if the accefs of air be only partially prevented, the metallic veffels are more violently acted upon ; but if they are of fufficient ftrength, and very fmall chinks afford vent to the air, the fmoke indeed penetrates through, but gently, and without burfting, as I twice experienced in about half a fcruple of this calx, with which I filled a brafs rofe, and ftopped the aperture with a ftrong fcrew ; for in this cafe the vapour made its way through the pores with a hiffing noife.

§ iv. *Means by which the fulminating Property may be deftroyed.*

This may be effected by various methods, and that even without additament.

(a) For inftance, by fire alone, flowly and cautioufly increafed : let a degree of heat at firft be employed near to that which ufually occafions the explofion ; this muft immediately be flackened a little, and thus alternately be increafed and diminifhed : upon continuing this operation a long time, the aurum fulminans gradually becomes capable of refifting a fire more and more intenfe, at length grows of an obfcure black, and lofes all its fulminating properties : this experiment requires confiderable pa-

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tience; for, unlefs the fire be fkilfully re-
gulated, and the fmalleft agitation and fric-
tion avoided, the powder explodes at once
with its ufual vehemence, and flies off in
the form of vapour.

(B) This effect is more commodioufly
obtained by the addition of a dry fubftance
of any fort, provided it be well pulverized,
and intimately mixed with the aurum ful-
minans by trituration, fo that the particles
of the latter may be feparated as much as
poffible; for this being done (which may
be eafily tried with fmall portions) the mix-
ture may fafely be expofed to the fire.

Sulphur has been long ufed for this pur-
pofe in the following way:—let powder of
fulphur be mixed with an equal weight, or
half its weight, of aurum fulminans, then
melted for a fhort time with a gentle heat
without fmoke, after this with evaporation,
and, finally, burned with deflagration : this
is done much more eafily by putting the mix-
ture by degrees into a crucible previoufly fo
heated, that the fulphur will flame upon
touching it; for in this cafe, although a few
grains decrepitate, they are not difperfed.
This may be effected with ftill greater eafe,
by adding the aurum fulminans gradually to
the fulphur in fufion.

The falts, either alkaline or middle, are
fufficient for this purpofe, and are ufed with
great advantage, becaufe they may be after-
wards feparated by ablution.

5   This

This operation fucceeds alfo with the earths, nay, with concentrated vitriolic acid, and other liquors, as we fhall afterwards fee (§ VIII. and IX). In a word, aurum fulminans is deprived of its fulminating property, if expofed to a degree of heat fufficient to caufe the explofion, if at the fame time the fulmination be prevented by any means whatever, even by external force.

§ V. *Chief Opinions concerning the Caufe of the Explofion.*

Various explanations of this explofive property are to be found among chemifts ; fome of which, being delivered in an unintelligible manner, we may properly pafs over, and confider the others as diftributed into four claffes ; for philofophers have thought, that this wonderful phænomenon might be attributed to a faline, a fulphureous, or an aerial principle, or, finally, to many of thefe jointly ; yet fome there are, who with juftice confider all the explanations hitherto given as infufficient.

§ VI. *Different Opinions concerning the Caufe, fuppofed to be faline.*

Thofe who attribute the fulmination to a faline principle, do not yet agree with regard to the fpecies of falt.

(A) Some confider the falited fixed al-kali (which is called fal digeftivus) adhering to the calx, and decrepitating in the heat, as the caufe of this phænomenon; but thefe gentlemen do not confider, that this falt is neither prefent nor regenerated, when the gold diffolved in nitrous acid, containing fal ammoniac, or in a mixture of nitrous and marine acids, is precipitated by volatile al-kali; and, befides, if the latter of thefe fo-lutions be precipitated by fixed alkali, the precipitate is not fulminating, though the digeftive falt in this cafe is prefent.

(B) Others have recourfe to common ni-tre, which is known to detonate with phlo-gifton : but here the fame difficulties oc-cur, for neither is nitre always prefent in the preparation of aurum fulminans, nor, when it is prefent, is the calx always found fulminating; befides, this falt does not de-tonate with the calx of gold, but on the contrary (by the method defcribed § IV.) ferves to reduce it.

(C) The nitre, called nitrum flammans, feems to be very different in its nature; this falt confifts of nitrous acid faturated with vo-latile alkali; and, from what has been already faid, the prefence of this fubftance in aurum fulminans is obvious; befides, it poffeffes the property of detonating, without the addition of phlogifton; and, befides, we are told by authors, that the vitriolic acid and fixed al-kali deftroy the fulminating property; the

2   former

former becaufe it is more powerful than the nitrous acid, and the latter becaufe it expels the volatile alkali. This opinion therefore carries with it an appearance of probability, and almoft all the moderns have embraced it. In order however to acquire a certain knowledge of this matter, if poffible, I inftituted a number of experiments, the chief of which I fhall now relate.

§ VII. *Fixed Alkali does not deftroy the fulminating Property by the Via humida.*

The fixed alkali does indeed deprive gold of its fulminating power, by fire, as defcribed in § IV. but in that cafe it acts in no other way than any other matter interpofed between the particles : but whether it acted in virtue of its alkaline quality, was tried in another way.

(A) Six parts of alkali of tartar were therefore well triturated in a glafs, with one of the calx, and a few drops of water. This being done, a little more water was poured on, and all the liquor evaporated in a digefting heat. During this operation no veftige of urinous fmell could be perceived : the mixture, when dried, and freed from the faline parts by ablution, not only fulminated, but with a noife far greater than ufual.

(B) The fame experiment was made in another way ; namely, one part of aurum

L 3 fulminans

fulminans was boiled for half an hour in 200 of cauftic lixivium; but its power was rather increafed than diminifhed by this: water was added, to prevent the lixivium from acquiring too great a degree of heat, which would of itfelf deftroy the fulminating property (§ IV.)

One circumftance I fhall remark, *viz.* that no difference of efficacy was obferved, whether the calx was precipitated from its menftruum quickly or flowly.

§ VIII. *Whether Acids deftroy the fulminating Property.*

As vitriolic acid requires near thrice a greater degree of heat to make it boil than pure water, it is no way furprizing that boiling in this acid fhould deftroy the fulminating quality, as before obferved : but, in order to determine whether that was the true and only caufe, the acid was fo far diluted with diftilled water, that it could not fuftain too high a degree of heat, and the aurum fulminans boiled in it for half an hour, when, after being well edulcorated, it exploded as ufual : nor does it, when triturated and digefted with the ftrongeft vitriolic acid, lofe any of its power, but by boiling many particles acquired the metallic fplendor of gold.

(B) The marine and nitrous acids, when boiling violently, poffefs a greater degree of heat

heat than boiling water, but inferior to that which is neceſſary for fulmination ; hence it happens, that the latter of theſe fluids not only fails of deſtroying the fulminating power, but the precipitate, while wet with this, decrepitates in the ſame way as if penetrated by water.

(c) But the marine acid diſſolves this calx more eaſily, and upon evaporation almoſt always reduces a part ; for this menſtruum naturally contains phlogiſton, which, by means of ſuperior attraction, it is obliged to yield to other bodies : but the ſolution itſelf, precipitated by fixed alkali, yields a calciform and fulminating gold. Whatever is not diſſolved by digeſtion, when well edulcorated ſeems to have loſt ſcarcely any thing.

(D) Upon adding vinegar, and diſtilling to dryneſs, the fulminating power is found to be deſtroyed : this however is only to be underſtood of the reſiduum, either not edulcorated, or reduced by means of heat.

§ IX. *The fulminating Property may be communicated to Gold, without the Intervention of nitrous Acid.*

In order to diſcover whether the nitrous acid be altogether neceſſary ; and alſo how the proceſs would ſucceed without the marine acid, the following experiments were undertaken.

L 4   (A) A

(A) A calx of gold (not fulminating)
boiled in vitriolic acid a little diluted,
yielded a yellow folution, for the precipita-
tion of which a large quantity of cauſtic
volatile alkali was neceſſary: the precipi-
tate was ſmall, but, after being edulcorated,
fulminated by heat.

(B) Another portion, boiled in nitrous
acid perfectly freed from marine acid by
means of ſilver, yielded, though not without
boiling violently, a red folution, of the ſame
colour as that of platina in aqua regia: this,
upon the ſimple addition of water, let fall
a calx, which, digeſted with cauſtic vola-
tile alkali edulcorated and dried, exploded
in the heat in the ſame way as gold precipi-
tated from the nitrous acid by cauſtic vo-
latile alkali, when waſhed and dried.

(c) Of all acids the muriatic beſt dif-
folves the inert calx of gold; even without
heat it diſſolves it readily: a folution of this
kind was precipitated by volatile alkali, as
before, and the ſediment, when waſhed and
dried, fulminated as uſual.

§ x.   *The Fulmination is not effected by a
Nitrum Flammans.*

In order the better to underſtand the de-
tonating property of the nitrum flammans,
let a portion of it be put into a cold glaſs,
then let the heat be raiſed as quick as poſ-
ſible,

fible, yet no detonation enfues, but the falt is refolved into vapour, and flies off: let the glafs be hot at firft, and the falt will liquefy, but not detonate; but if it fall upon an ignited glafs, it kindles and deflagrates, with a noife and a yellow flame: it is in vain therefore to affign this falt as the caufe of the fulmination.—Befides,

(A) The found of this detonation is not at all correfpondent to that occafioned by fulmination; but let us fuppofe it to be en-creafed by the weight of the fuperincumbent particles of gold, which prevent it from breaking forth, until the tendency to ex-plofion, increafing more and more, becomes at length able to remove the obftacle: but fimple detonation, unimpeded, requires a heat equal to ignition; when impeded it fhould therefore require a greater degree: now aurum fulminans requires a much fmaller heat, therefore fome other caufe be-fides detonation muft operate here.

(B) The precipitate of gold, which does not fulminate, I have endeavoured to unite by dry triture with nitrum flammans; but by this method could obtain nothing more than a powder which crackled in the heat.

(C) As the falt is fo eafily foluble in wa-ter as readily to attract humidity from the atmofphere, I thought that (if prefent in au-rum fulminans) it might be feparated by boiling: one part of it was therefore boil-ed with 600 of diftilled water for a whole hour,

hour, and after the interval of a day the same was boiled with 600 parts of fresh water for the same length of time, but in vain, for the powder fulminated with as great violence as before.—We may here observe the gradual efficacy of water : thus, if gold precipitated from the menstruum be not edulcorated, it scarcely fulminates at all; if washed a little with cold water it explodes indeed, but with a very obtuse sound, and a diffused flash; but if it be washed with a large quantity of water, or with hot water, it occasions an acute sound and an obscure flash. The efficacy of the water, when brought to this degree, is neither encreased nor diminished by boiling, as far as the ear can judge, which we are obliged to trust to, so long as we are destitute of a more accurate measure.

No one can wonder at the destruction of the fulminating quality in Papin's digester, upon considering the degree of heat which it there sustains (§ iv).

(d) Gold dissolved in dephlogisticated marine acid, and precipitated by volatile alkali, possesses the fulminating property, though nitrous acid has never touched it. If any one imagines that gold dissolved in aqua regia can never (by the humid way) be perfectly freed from nitrous acid, he must at least confess that that acid is altogether absent when dephlogisticated marine acid is employed to dissolve the gold : this acid
contains

contains a certain quantity of phlogifton, which it is obliged to yield to manganefe, and then becomes a yellow vapour, which diffolves all metals, by taking from them that quantity of phlogifton which would otherwife impede the folution ; and the acid itfelf is thus reftored to its natural ftate, and the combinations thus formed yield metallic falts containing a perfect marine acid.

From all this we conclude, that, even though the nitrum flammans were, which it is not, fufficient to explain the phænomena, yet it could not be admitted as the true and efficient caufe.

§ xi. *Volatile Alkali neceffary to the Fulmination.*

(A) In order to difcover what the volatile alkali contributed to this effect, a non-fulminating precipitate was digefted for fome hours in cauftic volatile alkali, afterwards edulcorated and dried : this fulminated perfectly.

(B) Left fome fufpicion fhould remain, of a remnant of the aqua regia adhering to the precipitate, notwithftanding the edulcoration, the experiment was repeated in this way : after digeftion for 24 hours in vitriolic acid, the precipitate was wafhed in pure water, then immerfed in aqueous and fpirituous folutions of alkali, both mild and cauftic ; but the event was the fame.

(c) An

(c) An inert calx of gold, by fimple di-
geftion in a folution of any falt containing
volatile alkali, whether the faturating acid
be vitriolic, nitrous, or marine, poffeffes
the fulminating property. The golden calx
is found increafed in weight about 0,2, and
the refidua of the ammoniacal folution con-
tain a fuperabundant acid : therefore the non-
fulminating calx of gold is capable of ab-
ftracting a certain quantity of volatile alkali
from the ammoniacal falts ; which portion
may again be feparated by diftilling the au-
rum fulminans well wafhed with vitriolic
acid ; for in the neck of the retort a vitrio-
lated volatile alkali is found fublimed.

(D) Finally, we fhould recollect that
gold cannot receive the fulminating proper-
ty without volatile alkali (§ 11).

§ XII. *Whether the Fulmination be effected
by a Sulphur.*

Moft of the ancient chemifts, and not a
few of the moderns, fpeak of a certain folar
fulphur, nay, fome contend that gold is
wholly a fulphur ; hence they derive the ef-
fects produced in the prefent cafe, endea-
vouring to perfuade themfelves and others
that here the fame principles co-exift as in
gun-powder and pulvis fulminans, namely,
fulphur, nitre, and tartar. But opinions like
thefe, at once fubtile and obfcure, we fhall
leave involved in their own darknefs.

The

The following obfervations will fhew that it is without reafon any fulphur is fufpected.

(A) Of late the fulmination has been attributed to a nitrous fulphur, generated in the precipitation, and adhering to the calx. The wonderful fulminating property of this calx is fuppofed to be fufficiently accounted for by the detonation of nitre; but the prefence of it in aurum fulminans has hitherto been fought after in vain. As vitriolic fulphur may be diffolved in a cauftic lixivium, and precipitated by acids, it feems probable from analogy that the fame property fhould belong to nitrous fulphur; but upon boiling in a cauftic lixivium (§ VII.) the fulminating power is found entire, and, upon the addition of acids to the lixivium, no particular fmell is obferved, and the gold is precipitated, but in exceeding fmall quantity.

(B) I have alfo employed vitriolic ether, that moft powerful menftruum of all inflammable bodies; this, on digeftion for fome days, begins to be tinged yellow, a golden pellicle appears upon the furface of the liquor, nay, a few grains of the calx lying at the bottom exhibit the fplendor of gold: upon evaporation to drynefs this folution yields fplendid gold, not at all fulminating.

Gold feparated by ether from aqua regia, deftitute of volatile alkali, when precipitated

by

by volatile alkali fulminates; but is totally void of that property, when thrown down by fixed alkali.

(c) Common fulphur is not foluble in fpirit of wine, unlefs when both thefe fubstances meet in the form of vapour; but we could not thence venture to conclude the fame of nitrous fulphur: I therefore digest-ed aurum fulminans for eight days in recti-fied fpirit of wine, but neither was the li-quor tinged, nor did any thing remain on evaporation, nor was the calx found to be changed.

It is worthy of obfervation, that the non-fulminating calx of gold, upon digestion for a few days in rectified fpirit of wine, grows black, and acquires a fulminating property, but weak, and fcarcely fimultaneous.

§ XIII. *Whether the Fulmination be occafioned by Aerial Acid.*

That fubftance which enters into the compofition of certain bodies, which, though very much refembling air, is fubftantially different from it, has been called by modern writers fixed air, although it really is a true and diftinct acid: fome contend that this forms the bond of union between the par-ticles of bodies, and in that ftate is fixed, and deprived of its elafticity; and that when a confiderable quantity of this recovers its elafticity at once, it muft ftrike violently upon

upon the atmofpheric air, thereby exciting undulations, and confequently a found, which is various according to circumftances.

They think, that in the prefent cafe the gold in folution lofes its fixed air, which it again recovers in ftill greater quantity during the precipitation, as the calx is found encreafed in weight;—the precipitate being then expofed to fire, this aerial matter is fuddenly forced to quit the calx, notwithftanding the weight of the particles of gold ; by means of which, however, the eruption being impeded, is made far more violent ; hence the extraordinary noife.—The following obfervations will fhew clearly that in this inftance the fixed air does not act in this cafe.

(A) The elaftic fluid which may be collected during the fulmination, is not abforbed by water, nor does it precipitate lime from that fluid (§ 111. c).

(B) Gold precipitated by mild fixed alkali, does not fulminate, unlefs the menftruum contains volatile alkali.

(c) Gold precipitated by cauftic as well as mild volatile alkali, fulminates.

(D) Gold in its precipitation rejects the aerial acid.

§ xiv. *The Phænomenon of Fulmination explained.*

From what has been faid it is plain that the vitriolic and marine acids are no lefs favourable

vourable to fulmination than the nitrous (§ IX.) yet that neither of thefe is otherwife neceffary than as diffolving and attenuating the metal (§ XI.) ; and finally, that no fulmination takes place without volatile alkali (§ XI.) : the queftion therefore is, how the volatile alkali acts in this cafe ? To this queftion I fhall endeavour to give the beft anfwer which experience has pointed out.

(A) From the very nature of the thing it is plain that fo great a report, and fo violent an explofion, could not happen but by means of the copious and inftantaneous eruption of fome elaftic fluid violently ftriking the common air ; and that this is the cafe in the fulmination we have already obferved (§ III. G) ; but, for the better underftanding this operation, it is neceffary to confider the conftituent parts of aurum fulminans, namely, the volatile alkali and the calx of gold.

(B) It cannot be doubted that volatile alkali always contains phlogifton : to pafs over other proofs, it may be fufficient to mention its detonation with nitre. Now this phlogifton may be feparated by means of a fuperior attraction ; fo that the volatile alkali is decompofed, and the refiduum diffipated in the form of an elaftic fluid altogether fimilar to that which is extricated during the fulmination : the fource then from whence the elaftic fluid is derived is obvious ; it remains

mains to examine the medium by which the volatile alkali is dephlogifticated.

(c) In thofe metals which are called per-fect, fo great is the firmnefs of texture, and fo clofe the connection of the earthy prin-ciple with the phlogifton, that by means of fire alone thefe principles cannot be difu-nited; but when diffolved by acid menftrua, they muft neceffarily lofe a portion of their phlogifton, and therefore, when afterwards precipitated by alkalis, which cannot fupply the lofs, they fall down in a calcined ftate: they however attract phlogifton fo forcibly that they can be again reduced to a metallic ftate without additament, merely by an in-tenfe heat penetrating the veffels. Gold therefore is calcined by folution; and this may be laid down as a fundamental pofition, being exprefly treated of, and, if I miftake not, undeniably demonftrated, in another place.

(D) Let the powder, now confifting of calx of gold and volatile alkali intimately united, be expofed to an heat gradually in-creafing, and let us examine what will be the confequence:—the calx, which is united with the volatile alkali, by the affiftance of a gentle heat feizes its phlogifton, and when this is taken away the refiduum of the falt is inftantaneoufly expanded into the form of an elaftic fluid, which is performed with fo much violence, that the air muft yield a very acute found. The calx may indeed be re-

duced by means of a very intenfe heat alone ; in which procefs the heat is decompofed, and yields its phlogifton to the calx, upon which the other principle, the pure air, is fet at liberty. But in the prefent inftance a fmaller degree of heat feems to be neceffary than when the volatile alkali is abfent ; hence we may impute the reduction chiefly to it, although it can fcarcely be denied that fome particles are reduced by the heat alone. This we collect from the obfcure flafh ; for light, fo far as experiment has yet fhewn, is nothing more than the matter of heat, with a fuperabundance of phlogifton : a part therefore of the calx being reduced by the phlogifton of the heat, the pure air (the other ingredient) is fet at liberty, and attacks the fuperfluous volatile alkali (which is now hot) and is fo loaded with the phlogifton of the alkali that it exhibits the appearance of light : for this cannot be attributed to the furrounding air, as the phænomenon takes place even in aerial acid. But that the volatile alkali can in this way produce a flafh, is evidently fhewn by another experiment : for if this falt be thrown into an hot crucible, it inftantly exhibits a flafh.—The volatile alkali, in its ordinary temperature, does not yield its phlogifton to pure air ; but that principle, being of itfelf very fugitive, upon the accefs of heat is much more eafily fet at liberty, and unites with the pure air.

A fingle

A fingle cubic inch of gun-powder ge-
nerates about 244 of elaftic fluid, but the
fame quantity of aurum fulminans yields at
leaft four times as much; and hence we
may eafily underftand the difference in their
explofive force.

The above explanation of the report,
founded upon the knowledge of the compo-
fition of heat, and of aurum fulminans,
feems abundantly fatisfactory, but fome
phænomena ftill remain not fufficiently ac-
counted for.

That careful calcination fhould deftroy
the fulminating property, is not to be won-
dered at (§ IV. A), as the volatile alkali is
the indifpenfable material caufe (§ XI.); but
the peculiar alacrity which it acquires be-
fore the explofive force is totally extinguifh-
ed, depends upon the nature of the mate-
rials, and of the operation. Thus the heat,
when inferior to that neceffary for fulmina-
tion, acts upon both the principles of the
aurum fulminans, it prepares the metallic
calx for a more violent attraction for phlo-
gifton; it alfo acts upon the phlogifton of
the volatile alkali, and loofens its connec-
tion: thefe two circumftances muft tend to
the union producing the explofion. But
this effect has a maximum, and at this pe-
riod the flighteft friction fupplies the de-
fect of neceffary heat, and produces the ful-
mination. The calcined gold alfo feems to
collect and fix the matter of heat, though

M 2 ftill

ftill infufficient, by means of its phlogifton, in a certain degree; fo that, by means of friction, though but very flight, it becomes capable of exerting its force: but when the heating is often repeated without producing its effect, the volatile alkali is by degrees diffipated, and at length fo much diminifh-ed that the calx becomes inert. That this diffipation is promoted by enlarging the fur-face is evident, and this explains the mode of action of the heterogeneous particles in-terpofed between thofe of the calx (§ IV. B).

But if aurum fulminans is capable of pro-ducing fuch a prodigious quantity of elaftic fluid, how does it happen that it remains mute and inert when reduced in clofe vef-fels? This I take to be the reafon—every elaftic fluid in the act of breaking forth re-quires a fpace to expand in; if this be want-ing it remains fixed, as has been already de-monftrated: taking this for granted, a calx of gold cannot be reduced in clofe veffels either by heat or by the phlogifton of volatile alkali; for in either cafe it muft evolve its elaftic fluid, which by fuppofition it cannot do. Nothing remains to folve this difficulty but the ignition of the furround-ing metal, by means of which the calx, in virtue of its fuperior attraction, feizes the phlogifton of the metal, which that fub-ftance, here as well as in other inftances, is capable of lofing without the eruption or abforption of any fluid whatever.

Whether

Whether this explanation be satisfactory or not I leave to the decision of the judicious.

(E) The stories told us by authors of the fulminating property of certain metals, particularly copper and silver, have not, I confess, been verified by my experiments; so they have either been silent upon some circumstances necessary in the operation, or perhaps have been deceived by the detonation of nitrum flammans, or some other accidental occurrence. It is not sufficient for the volatile alkali to adhere to the precipitate; for platina thrown down by this alkali retains a portion of the alkali very obstinately, but yet does not fulminate on exposure to fire. Besides the presence of volatile alkali, it seems to be necessary that the metallic calx should be reducible by a gentle heat, in order to decompose it: but every explosion is not to be derived from the same causes; nay, in this respect aurum fulminans, gun-powder, and pulvis fulminans, differ very much, though they agree in several particulars.

DISSER-

DISSERTATION XVIII.

OF

PLATINA.

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§ 1. *Introduction.*

D. SCHEFFER was the firſt who properly examined the new metal which was lately found in America, and brought to us under the name of platina. In the year 1752 he inveſtigated its properties, and demonſtrated that in perfection it approached to gold, and therefore gave it the name of white gold: after him many experienced chemiſts, with laudable induſtry, have laboured in the accurate examination of this ſubſtance; ſo that we may ſay with juſtice, that there are few of the metals, though known and uſed for eighteen centuries and upwards, which have undergone ſo accurate an inveſtigation, by means of the

moſt

moft acute experiments; notwithftanding this, however, many circumftances occur to an enquirer which are ftill obfcure, and not fufficiently elucidated by experiment, and hence have arifen many diffenfions. Some of thefe points I hope I fhall be able to elucidate, efpecially as I am in poffeffion of a fufficient quantity of platina, by the gene-rofity of the Baron Claudius Alftromer, who had brought it with him upon his return from Spain.

§ 11. *Platina precipitated by Means of vegetable Alkali.*

This new metal, diffolved in aqua regia, exhibits, upon precipitation, many peculiar properties worthy of accurate examination. —We fhall begin by the precipitate occa-fioned by vegetable alkali.

(A) Aqua regis, compofed of nitrous and marine acid, attacks platina, exhibiting a folution at firft yellow, but which when further loaded grows red, and the colour grows the deeper as the folution is more loaded with the metal. Upon evaporation cryftals are produced, of a deep red colour, frequently opake, but fometimes pellucid, in general very fmall, irregular, and refem-bling angular grains, the real form of which I have not yet been able to difcover.

(B) Thefe cryftals, wafhed and well dried, require far more water than gypfum

M 4   does

does to diffolve them by boiling. The folu-
tion is yellow, and feparates fome pale floc-
culi, which are probably martial: vege-
table alkali does not difturb the folution,
nay, the cauftic lixivium of this alkali, when
hot, does not diffolve the cryftals, or at leaft
attacks them very faintly, even although a
digefting heat be applied, and the liquor
evaporated to drynefs. By this method the
colour of the cryftals is a little weakened,
the aerated mineral alkali diffolved in water
takes them up and grows yellow, yet it re-
mains clear, and in many hours does not
depofit any thing, but by evaporating to
drynefs it decompofes them.

(c) The folution (A) upon the addition
of a little vegetable alkali, either aerated or
cauftic, immediately, or at leaft in a few
minutes, depofits fmall ponderous red cryf-
tals, of a different nature from thofe men-
tioned in B; thefe are fometimes diftinctly
octaedral, and foluble in water; they are de-
compofed with difficulty by the mineral, but
are not changed by the vegetable alkali.

But if the alkaline falt be added in larger
quantity, the fuperfluous acid being fatu-
rated, there is feparated a yellow fpongy
powder infoluble in water, which exhibits
a calx of platina.

The clear folution (A) reduced fo far by
evaporation, that the remaining liquor con-
fifted only of a few drops, upon the addi-
tion of the alkali exhibited the fame phæ-
nomena

nomena as mentioned above, except that the cryftalline powder was of a deeper yellow.

(D) Inftead of the vegetable alkali, let the fame, faturated with an acid, either vitriolic, nitrous, marine, or acetous, be employed; neverthelefs, the red cryftalline molecules appear; but by this method the whole of the platina cannot be feparated, as in the foregoing paragraph (c); for the folution retains a deep yellow colour, however abundantly thefe falts be added, nor does any genuine calx of platina fall, except upon the addition of an alkali; for which purpofe either the mineral or vegetable will ferve.

(E) I took the fame weight of platina as in A, and tried it with an equal bulk of menftruum, confifting wholly of nitrous acid; to which was added of common falt four times the weight of the metal: this nitrous acid was taken out of the fame bottle as in A; in a digefting heat all the platina was diffolved; the folution was red, but more dilute than that in A; a yellow powder floated on the furface, but at the bottom a larger quantity of the fame was found.

The clear folution, upon the addition of the fmalleft quantity of vegetable alkali, depofited a copious yellow powder, which yet was foluble in a fufficient quantity of water. The neutral falts, with a vegetable alkaline bafe, alfo precipitated a fimilar powder more

<div align="right">flowly</div>

flowly and more cryftalline; but the mine-
ral alkali, though employed in fifty times
the quantity of the vegetable alkali, does
not at all difturb the folution, the abundant
acid not being yet faturated.

The powder collected at the bottom was
totally foluble in water, and in its proper-
ties agrees with the cryftalline powder fpon-
taneoufly feparated in B, but is of a yellow
colour.

(F) I repeated the experiment with the
fame quantities, but inftead of the nitrous
acid and fea-falt, I ufed the marine acid
and nitre, well depurated. In this experi-
ment the platina yielded a folution of a
golden colour, together with a greenifh
powder, moftly granulated, the more fub-
tile part of which floated on the furface.

The clear folution did not depofit any
thing upon the addition of vegetable alkali,
until all the fuperfluous acid was faturated,
but then yielded a metallic calx infoluble
in water.

The green powder is wholly foluble in a
fufficient quantity of water, and agrees, as to
its properties, with the cryftalline powder
occafioned by the vegetable alkali in C
and D.

(G) Platina precipitated from aqua regia
by a fufficient quantity of mineral alkali,
well wafhed, and diffolved in marine acid,
upon the addition of vegetable alkali imme-
diately lets fall a cryftalline powder; which

is

is also the case with nitre and other neutral salts, whose basis is the vegetable alkali. I employed the additaments, especially the neutral, dry, or at least well saturated solutions.

(H) The case is the same with calx of platina dissolved in vitriolic acid.

(I) The precipitate of platina is taken up also in the same way by nitrous acid freed from all admixture of the marine; but this nitrous solution exhibits different properties with the vegetable alkali from those of the muriatic solution in G; for I could not obtain a distinct saline precipitate, without the addition of marine acid.

(K) That which I have now affirmed of the calx of platina, is also true of the precipitate occasioned by vegetable alkali, after the deposition of the saline powder (c).

(L) Upon comparing these experiments it will readily appear, 1st, That the precipitate which is first thrown down, on the addition of vegetable alkali to solutions of platina, is a saline substance, and different from the calx of this metal (c) : 2d, That this saline precipitate is composed of calcined platina, marine acid, and vegetable alkali (D E F G and I) : 3d, That by means of vitriolic acid a precipitate analogous to this may be obtained, composed of calcined platina and vegetable alkali, joined to vitriolic acid (H) : 4th, That the whole solution of platina cannot be precipitated in the form

of

of a triple falt by the vegetable alkali, either difengaged, or otherwife; but that a determined limit takes place, upon paffing which it yields a metallic calx in the ufual way, like other metals.

§ III. *Platina precipitated by Means of the Mineral Alkali.*

The moft celebrated chemift of the age, Mr. Margraaf, denies that a folution of platina can be precipitated by mineral alkali, which Dr. Lewis confirms on repeating the experiment. Now, as none of the metals adhere to acids with fo much force as to refufe quitting them on the addition of mineral alkali, platina would form a very fingular exception; I therefore thought this circumftance worthy of particular examination.

(A) I tried the common folution of platina with a folution of mineral alkali; each drop, on falling in, excited a violent effervefcence, but no precipitate appeared. I ftill continued, however, to drop in the alkali, and at length the folution began to grow turbid, and a fpongy yellow powder was precipitated, confifting of a genuine calx of platina.

I afterwards effected the fame more quickly, by employing the mineral alkali dry, and fpontaneoufly calcined.

(B) In

(B) In order the better to determine the different efficacies of the fixed alkalis, I divided a folution of platina, as yet very acid, into two equal parts; to one of them I added fmall portions of the vegetable, and to the other an equal weight of pieces of mineral alkali: between the addition of every two pieces I waited five minutes, till the effervefcence had ceafed. After the third addition, I obferved fmall cryftals appearing in the firft, partly on the furface, partly on the bottom; while at the fame time no feparation of calcined platina appeared in the latter, until after the addition of fifty-fix times the quantity of the vegetable alkali; the difference was, however, ftill greater than at firft appears from this experiment; for the vegetable alkali was cryftallized, and therefore charged with the water neceffary to its cryftalline form; whereas the mineral alkali was fpontaneoufly calcined; and, although in equal weights of thefe two alkalis, the pure alkaline parts are as 3 to 2, yet 3 parts of vegetable alkali faturated only 1,71 of this aqua regia, while 2 of the mineral alkali took up about 2,6.

A difference fo great as this, together with the then undifcovered faline nature of the precipitate firft thrown down by the vegetable alkali, undoubtedly contributed to deceive thefe experienced and defervedly admired chemifts; a circumftance which is by no means wonderful.

(c) In

(c) In refpect of precipitation, therefore, the mineral alkali fuffers no impeachment, but rather the vegetable exhibits a very fingular habitude with regard to diffolved platina, which it does not poffefs with any other metal.

§ IV. *Platina precipitated by Means of volatile Alkali.*

Dr. Lewis was the firft who fhewed that platina may be precipitated by fal ammoniac; this is a fingular phænomenon, which we fhould by no means expect from a neutral falt, and which I have never yet feen explained.—The following obfervations are intended to illuftrate this procefs.

(A) The volatile alkali, whether mild or cauftic, precipitates platina in the fame way as defcribed § II. c; at firft it throws down the metal in a faline form; and, although the grains be fmall, yet they are of a cryftalline fhape; which upon examination is fometimes found to be diftinctly octaedral.

Their colour varies according to the intenfity of the folution; when red, it depofits red cryftals; and when more dilute, no other than yellow. After the fuperabundant acid has been faturated, the fame alkali precipitates the platina truly calcined.

(B) The faline precipitate, though flowly taken up by water, yet if the quantity of

water

water be fufficient is totally diffolved, and may by evaporation be reduced to more regular cryftals.

The mineral alkali diffolves thefe cryftals ; but fcarcely any figns of decompofition appear, unlefs the yellow folution, evaporated to drynefs, be again diffolved in water ; for then the metallic calx refts at the bottom, and the folution wants the yellow colour. The vegetable alkali has fcarcely any effect in this way, for after repeated exficcation, the folution remains clear and yellow ; but here it appears very probable, that this alkali takes the place of the volatile, for in larger quantities, and efpecially when the cauftic vegetable alkali is employed, the expulfion of the volatile alkali is in fome degree manifeft by the fmell.

(c) The volatile alkali, faturated with any acid, throws down a fimilar faline precipitate, at leaft it produces the effect, whether it be joined with vitriolic, nitrous, or marine acids ; but thefe neutral falts precipitate only a determined quantity of platina ; for, after the ceffation of their effect, the remaining liquor, upon the addition of vegetable or volatile alkali, lets fall a pure calx.

(D) The calx of platina, precipitated by mineral alkali, and then diffolved in any fimple acid, as vitriolic, nitrous, or marine, exhibits nearly the fame phænomena with

2   volatile

volatile alkali, whether difengaged or other-
wife, as it does with the vegetable alkali.

(E) Upon confidering thefe experiments,
therefore, we may conclude, that platina,
diffolved in acids, forms at firft, as well
with the volatile as with the vegetable al-
kali, a triple falt, which is difficultly folu-
ble, and therefore almoft always falls in the
manner of a precipitate, unlefs the quantity
of water be more abundant than ordinary.

§ v. *Platina precipitated by Means of Lime.*

(A) Lime, whether aerated or cauftic,
precipitates platina in the fame manner as
the mineral alkali does, without any cryf-
talline appearance.

(B) Upon the confideration of thefe phæ-
nomena, there appears a fingular analogy
between the vegetable and volatile alkalis,
and between the mineral alkali and lime.
A like agreement takes place between thefe
fubftances in other inftances. I fhall men-
tion one remarkable example :—alum, ex-
tracted from argillaceous matters, by means
of vitriolic acid, fometimes cannot, without
difficulty, be reduced to folid regular cryf-
tals ; but by the addition of a fmall quan-
tity of vegetable alkali this inconvenience
may be remedied, and the volatile alkali
produces the fame effect. It may be fuf-

10   pected,

pected, that this is owing to the abstraction
of superabundant acid ; but it cannot be
done either by mineral alkali or lime, both
of which are capable of saturating the acid ;
besides, not only the vegetable and volatile
alkalis assist the crystallization of alum
when they are disengaged, but also when
united with acid, which makes the resem-
blance complete. The matrixes of alum
frequently contain the proper alkali, either
naturally combined with them, or superad-
ded in the roasting ; and hence it is seldom
necessary, in the preparation of alum, to pro-
mote the crystallization by alkalis.

§ vi. *Difficulty with which Platina is fused.*

It is well established, that of all known
metals platina is the most difficult of fu-
sion ; for, in its perfect state, it is scarcely
to be overcome, except in the focus of a
burning mirror ; while mercury, on the
contrary, finds sufficient heat in the coldest
winter to preserve a fluid form ; but not long
since, the celebrated Delisle discovered a me-
thod by which platina may be fused even by
a common fire. Thus the precipitate ob-
tained by sal ammoniac, exposed without
additament to a most violent degree of heat
in a blast-furnace, yields a polished metallic
globule, which is sometimes sufficiently mal-
leable. I have repeated the experiment with
success ; but in order to obtain the regulus

in

in a malleable ftate, the quantity muft be very fmall, and the heat very intenfe.

(A) I tried whether platina, precipitated by fal ammoniac, could be fufed by the blow-pipe. In order to make a fmall portion remain on the charcoal, notwithftanding a violent blaft, I added to it a little microcofmic falt in fufion, and in a few minutes obtained a polifhed globule, but fo very fmall, that when beaten out it yielded a circular plate of only one line in diameter. I found means, by the addition of microcofmic falt, to reduce feven or eight of thefe planes into one mafs, equal in bulk to the head of a common pin; and after beating this out, I once reduced it again to a globular form, ftill preferving its malleability, but could not fufe it again; for, being imperfectly fufed, it broke under the hammer.

Borax is fcarcely of any ufe in this operation, for it expands upon the coal together with the precipitate.

(B) The faline precipitate thrown down by volatile alkali, treated in the fame manner, exhibits the fame properties as the foregoing.

(c) I found fo great refemblance between the precipitate occafioned by the volatile and by the vegetable alkali, that I fhould have concluded, that in this experiment they would prove to be fimilar; but I have often had occafion to fee how

5   little

little analogy is to be confided in ; I there-
fore made the experiment with the cryftals
obtained by vegetable alkali, and found my
conjecture to be juft.

(D) The cryftals obtained by fpontaneous
evaporation (§ 11. B) after completely drying,
when added to the microcofmic falt in fu-
fion, decrepitate more violently than thofe
obtained by means of the alkaline falt (§ 11.
c ; and IV. A). Somewhat, however, re-
mains in the fixed mafs, which is not un-
frequently reduced upon its furface, yielding
a pellicle of a filver colour ; but I have not
hitherto been able to reduce it to a globule.
Thus far I have advanced, namely, to ob-
tain the platina collected together within
the falt, in a white mafs of an irregular
form ; but the particles of this fpongy
mafs were feparable by mechanical force.
This is the cafe with the calxes of platina,
by whatever alkali they are precipitated
(§ III. A ; II. C ; and IV. A) ; therefore it
feems very probable, that the principle which
difpofes to fufion is fupplied by the vege-
table, and alfo by the volatile alkali.

§ VII. *Properties of depurated Platina.*

By the method now defcribed, I obtained
feveral very beautiful pieces of regulus ; they
were, it is true, exceeding fmall, but won-
derfully malleable ; and were freed from
iron by repeated fufion with microcofmic
falt,

falt, more completely than by any other
method hitherto known. It is proper to
obferve, that the crude platina was felected,
and repeatedly boiled in marine acid, until
the menftruum could not extract any more
iron. By this procefs 0,05 were feparated,
the remaining part of the iron being doubt-
lefs fo enveloped by the particles of platina
that the boiling acid cannot have accefs to
them. This platina, after wafhing, was dif-
folved in aqua regia freed from all iron,
and then precipitated by the pureft fal am-
moniac. I fhall therefore defcribe the qua-
lities of the regulus obtained from this pre-
cipitate.

(A) Its colour is that of the pureft filver.

(B) The very fmall globules are wonder-
fully malleable; but when many of thefe are
collected together they can fcarcely be fo
perfectly fufed as to preferve the fame de-
gree of malleability.

(c) A magnet, though of great power,
does not act upon them in the leaft, nor is
the moft delicate magnetic needle affected
by them.

(D) They cannot be diffolved by any
fimple menftruum, except the dephlogifti-
cated marine acid.

(E) Aqua regia, compofed of the acids
mixed, diffolves them, is yellow at firft,
and, when more faturated, red ; on evapora-
tion the folution yields fhapelefs cryftalline
grains, though I muft confefs, that in the
place

place of thefe I have fometimes obtained
nothing more than a faline mafs.

(F) Their habits with alkalis, whether
difengaged or faturated with acids, are the
fame as above defcribed.

(G) The phlogifticated alkali, well fatu-
rated, and freed from the fmall portion of
Pruffian blue which it diffolves, occafions
no precipitation, but the colour of the fo-
lution is rendered darker. This lixivium
therefore diffolves platina, as well as fome
other metals. Not the fmalleft veftige of
Pruffian blue appears, which yet is evi-
dently feen upon the addition of a portion
of martial vitriol, amounting to only 0,001
of the platina contained in the folution,
although 0,001 of martial vitriol contains
only 0,00023 of iron.

§ VIII. *Whether Platina be a Metal diftinct
from all others.*

Although many of the moderns give pla-
tina a place among the metals, yet there are
fome naturalifts of high reputation who
confider it as nothing more than a mixture
of gold and iron. We fhall not here con-
fider the arguments on both fides, but reft
entirely upon the conclufions which follow
clearly from the preceding experiments.

(A) As to iron, there is no doubt of its
prefence in platina, as is evidently fhewn
both by the magnet and the phlogifticated

lixivium :

lixivium : but whoever examines the metals accurately will find that they never occur in a perfectly pure state. Gold is contaminated more or less with silver, copper, or iron ; silver with copper and arsenic ; copper with iron, and that generally in such a quantity as to be discernible, but sometimes in such small portions as to be concealed ; nickel contains cobalt; and so on. Let us now suppose that native platina is never found without iron ; yet it does not follow from thence that iron enters into it as one of its constituent principles.

(B) This iron may be artificially separated, or at least so much diminished as not to be in the smallest degree sensible, either to the magnet or the phlogisticated lixivium (§ VII.) With what appearance of probability then can it be said, that in depurated platina (which in 100,000 parts is supposed to contain 99,977 of gold) the nature and distinguishing properties can be so changeable as that a smaller quantity than 0,00023 of iron (§ VII. G.) shall operate so as to conceal the properties of both the ingredients ?

(c) I have long wished to get a piece of platina entirely crude, and unchanged by art ; for not only is iron supposed to be a principle of this metal, but it is asserted to be magnetic : it is known that grains of platina are found mixed with gold in the bowels of the earth, and that the gold is freed
from

from them in iron mills by means of mercury ; may not the magnetifm therefore be occafioned by the iron which adheres during this operation, as we know that iron receives that property by percuffion and other means ? — befides, a fuitable fituation, long continued, alfo generates that quantity ; and perhaps to this caufe may the magnetifm be owing, if it actually does take place in crude platina ; if not, it muft be entirely attributed to art.

In the year 1774 two Spaniards who had come to Upfal, from America, prefented me with two forts of platina, one of which had been wafhed with mercury, in order to feparate the gold ; the other rude, which they afferted had never been expofed to amalgamation. This latter was to me a very acceptable prefent ; but my pleafure foon vanifhed, for a few ounces of it, expofed to fire in a glafs cucurbit, fent forth mercurial vapours, which formed into globules on the neck of the veffel. As platina is mixed with particles of gold, there is very little probability that it ever comes to Europe pure : it may happen alfo that it repeatedly undergoes that operation, for even fuch as is brought to Europe yields grains of gold : when once deprived of the gold it is thrown out ; and this it moft probably is which, after a feries of years, is confidered as pure.

DISSER-

DISSERTATION XIX.

WHITE ORES OF IRON.

§ 1. *An accurate Knowledge of Ores necessary to the proper Treatment of them.*

OUR omnipotent Creator has provided for the use of man an inexhauftible ftore of natural bodies, which are to be found in the external covering of the globe; fome of thefe we have accidentally learned to employ to our advantage, others we have been urged by neceffity to feek ; and by flow degrees, and after many trials, we have difcovered the proper treatment of them : but the greateft number we ftill neglect as ufelefs, being ignorant of their value.

It

It is obvious, that in proportion as men become more perfectly acquainted with the virtues, qualities, and compofition of bodies, the more perfectly and eafily will they be able to apply them to their advantage and convenience.   Upon that particular, therefore, fhould our chief care be employed, for a proper acquaintance with the ftores of nature will certainly be followed by the application of them to ufe: neverthelefs, fo provident has nature been againft human ignorance and floth, that the rudeft labour is not without fignal advantage : thus in the darker ages we find the richeft minerals ufed as tributes, a circumftance which naturally followed the difcovery of them ; yet they were not valued in proportion to their goodnefs. When, by the experience of ages, the various qualities of thefe bodies were difcovered, the foundation of metallurgy began to be laid ; and in proportion as the fuperior fkill of men now enables them to obtain more metal from poorer veins, nature feems to have diminifhed the former fuperabundance of thefe productions.   The chemical knowledge of the prefent times would be too much enriched, if the former abundance fubfifted ; and on the other hand, the rude and unfkilful attempts of the firft inventors would be entirely ufelefs, had they been cramped by the fcarcity which is now found to take place.

§ 11. *Phy-*

§ 11. *Physical Qualities of the white Ores of Iron.*

These ores have received divers denominations, from the singular heat with which they are accompanied. In Germany they are called *stahlstein* or *stahlertz* (as the iron got from them could be changed into excellent steel) as also *weisse, eisenspat, pflintz,* and other names : in France they are called *mines de fer spatique,* although it must be confessed that they are not always spathous ; and that moreover many which are of a spathous texture, and loaded with iron, do not belong to this class.

(A) The texture of these minerals is almost the same as that of the calcareous stone, yet it is rarely found compact, and composed of impalpable particles ; it is sometimes squamous, sometimes granulated with small distinct particles, some of them shining, but in general it is spathous. We do not speak of them here in their complete and perfect state ; for the figure of their parts is more or less destroyed by spontaneous calcination, nay, the whole mass is at length resolved into a powder : sometimes it is found stalactitic, fistulous, and ramous, or even cellular, nay sometimes germinating like moss.

(B) They are sometimes, but very seldom, so hard as to strike fire with steel ; but

though

though (when found mixed with flint, and newly dug up) they are of this kind, yet they soon lose that property: in other respects, when perfect, they generally resemble calcareous stone, unless when exposed to the air for some time, by which the union of their parts is gradually diminished.

(c) The colour is white, but the surface which comes in contact with the air grows gradually brown, or even blackish; yet so long as the iron, which is converted into an ochre, remains in them, they have a ferruginous hue; but though the surface is thus changed, the internal parts remain the same, and upon filing or breaking exhibit the natural colour.

This change is effected by the air, not upon the iron, as is commonly believed, but upon the white calx of the manganese, which is dephlogisticated by the surrounding atmosphere; a circumstance which it is sufficient here to mention, as it will be more accurately explained hereafter (§ VII. G).

(D) The specific gravity of the ore, when perfect, varies between 3,640 and 3,810, and is diminished according to the degree of calcination. That ore, whose particles scarcely cohere, but are quite separated, is from 2,5 to 2,9; but that which is not perfectly corroded, from 3,3 to 3,6.

(E) The ore, whether perfect or calcined, is rarely attracted by the magnet, though the

the martial part fometimes amounts to near-
ly half the weight.

§ III. *Situation of thefe Ores in Mountains.*

The white ores of iron are found, but
very fparingly, in Sweden : Suartberger,
(*i. e.* Black Mountain) near Schifshytta, in
Dalekarlia, has its name from its furface,
which is grown black by calcination. This
mountain is high, and naked upon the fum-
mit, which is croffed by a broad calcareous
vein, with fhining particles of fpar, and a
white ore of iron, together with galena,
pfeudo galena, and black ore of iron, py-
rites, fchoerl, and garnet intermixed. In the
old mines at Hællefors, or the eaftern
mines, the rock itfelf appears to confift of a
white ore of iron. It is fometimes found
alfo in other mountains, but generally either
in fmall quantity or very poor in metal.

Germany is rich in thefe ores : many
mountains about Smalkald contain them :
in that which is called Stahlberger a broad
vein, almoft horizontal, occurs from twen-
ty-five to thirty fathom thick ; this confifts
of an irregular fpar, in which are difperfed
quartz, and pieces of the ore, which are
found of a better quality, in proportion as
they are more deeply feated. The pendent
fide, which is uppermoft, is compofed of a
fandy ftone from nine to twenty fathom
high, but the lower, which is the founda-
tion,

tion, is margaceous, and is found more in-
durated towards the lower parts, and at the
very loweſt is extruded by a blue mica; the
ſides ſcarcely cohere to the vein.

In Nauſſavia the whole mountain ſeems
to conſiſt of a yellowiſh ore of iron, certain
veins of which are accompanied with cop-
per, others with hæmatites.

In Upper Stiria, at Eiſenarg, is ſituated
Arzberg, in circuit 6,000 fathoms, in dia-
meter 900, and in height 450: it is de-
ſcribed by ſome as irregularly accumulated
and concreted, and as conſiſting of maſſes of
quartz, charged with argillaceous earth and
white ore of iron; but others contend that
the ore is there found not only in heaps but
alſo in various veins.

France and Spain produce great quantities
of theſe ores.

The examples above cited ſeem to indi-
cate that the white ores of iron are found
ſometimes in heaps, but that they alſo form
ſometimes veins, ſometimes ſtrata, and
ſometimes whole mountains. I have never
found that they contained any organized
bodies, a mark by which the moſt ancient
productions of the earth have been diſtin-
guiſhed.

§ IV. *Properties of theſe Ores examined by
the Blow-Pipe.*

Experiments, with this inſtrument, al-
though made upon ſmall pieces, yet in ge-
neral

neral ſhew the nature of the ſubſtance exa-
mined with conſiderable certainty, and point
out the method of treatment proper for
larger quantities; therefore it is that I am of
opinion we ſhould begin our experiments in
that way.

(A) The white ore of iron, expoſed to the
flame, at firſt is apt to decrepitate, and that
the more violently, as it is of a more cryſ-
talline texture; ſo that that which is of a
denſe texture, and whoſe particles are ſcarce-
ly diſcernible, decrepitates little or none : a
certain degree of ſpontaneous calcination alſo
overpowers this decrepitating quality.

Another, and a more remarkable effect
of the fire, is a ſudden change of colour:
the whiteneſs ſoon changes to a brown,
which quickly gives place to a blackneſs,
which cannot be diſcharged even by violent
and long-continued heat.

A piece of the ore, when blackened by
the fire, is always attracted by the magnet,
although, as is frequently the caſe, it had
not been obedient to it before.

But the ore alone is not fuſed without
great difficulty, though the fire be violent
and long continued. Upon fuſion it again
eludes the force of the magnet.

(B) A ſmall portion, added to a globule
of microcoſmic ſalt in fuſion, is diſſolved
with more or leſs efferveſcence, and imparts
an iron colour, that is, a greeniſh or a yel-
lowiſh

lowifh brown, which upon cooling grows weak, and at length entirely vanifhes.

When the globule, after cooling, is again foftened, not by the interior and blue cone of flame, but by the exterior and lefs defined part, a red colour is generated, which alfo vanifhes upon cooling; this is made more diftinct by the addition of a fmall piece of nitre, but upon cooling is weakened. Fufion by the blue cone, continued for fome time, extinguifhes the rednefs, fo that the iron tinge appears : in this way the red colour may be many times alternately difcharged and renewed.

When the globule is fuperfaturated with the falt, upon cooling it grows opake, white or black, according to the different quantities of the calx and the iron ; and in the latter cafe it fometimes poffeffes a metallic fplendor.

A variety in the proportion of the principles occafions great changes in the phænomena ;—thus the original effervefcence is both more vifible and more durable when the calx abounds. When the iron is deficient, its colour can fometimes fcarcely be difcerned ; and when the quantity of manganefe is very fmall, and that of iron large, the rednefs fcarcely appears without the addition of the nitre.

(c) The white ore of iron is diffolved in the fame manner by borax, *viz*. the effer-
vefcence

vefcence is more or lefs confpicuous, according to the quantity of calx.

The vitreous globule frequently acquires an obfcure reddifh yellow colour, which yet, upon the continued application of the blue cone, is totally deftroyed, the martial tinge remaining : but by nitre, or by foftening alone, which is effected by the exterior cone, the hyacinthine colour above mentioned again appears.—Thefe changes may be produced at pleafure.

By fuperfaturation the globule becomes opake, black or white.

(D) The mineral alkali fufed in a filver fpoon takes up the ore with an effervefcence more or lefs remarkable, yet divides it but little, nor is the milky globule rendered brown, unlefs by a larger addition, and a longer continued fire, and then it grows black.

(E) Thefe experiments fhew that the ore contains lime fomewhat filiceous, iron, and manganefe ; and although thefe ores may appear to many of little confequence, yet they have difcovered to me a new metal, which by other means could not be difcovered. The properties of manganefe, hereafter explained (§ VII.) will illuftrate this affertion more fully.

§ v. *Properties of thefe Ores examined by the Via Sicca.*

(A) 100 parts finely powdered, and exposed upon a tile to the fire, grow quickly black, and become obedient to the magnet; in this experiment fometimes red fpots appear here and there, occafioned by the admixture of pyrites. An heat of two or three hours occafions a lofs of weight different according to the variety of the ore; the lofs is at the leaft 15, and at the moft 40 affay pounds: by a longer continuance of the heat the lofs is not increafed, nor does the black colour difappear, nor are any figns of fufion to be obferved.

On calcination, no fmell is perceptible, unlefs there be an admixture of fome pyritous particles.

When the pieces are fufficiently roafted, and after cooling put into water, they often generate heat, and form a fort of limewater.

(B) In order to learn the nature of the fubftance expelled by fire, 100 of the pulverized ore was put into a fmall retort, to which was adapted a receiver, which by a lateral tube conducted the elaftic fluid into a glafs veffel full of water, and inverted; the fire was then gradually increafed, until the bottom of the retort began to grow foft; in the mean time a fmall quantity of liquor

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was found in the retort, but in the inverted glafs a large quantity of elaftic fluid.

The liquor in the receiver was found of an aqueous nature, but for the moft part fo fmall in bulk as fcarcely to be collected, feldom fo much as 0,1, and never exceeding 0,2. The ore, when perfect and cryftallized, ufually yields a little more water than when broken down by fpontaneous calcination, or when naturally denfer.

The elaftic fluid, when confined by mercury, fometimes occupied 30 cubic inches, but was generally lefs : on examining this it was found to be moftly abforbed by water, and to communicate to it a pungent acidulous tafte, together with the property of making the tincture of turnfole red. It precipitated lime-water, extinguifhed flame, and deftroyed animal life : thefe properties fhew it to be the aerial acid ; the portion which remains and refufes to unite with water, is common air, which doubtlefs was at firft contained in the retort. When the aerial acid is feparated by water, a fpecies of deflagration takes place; yet it fhould be obferved that inflammable air is almoft always abfent.

The black refiduum in the retort, though it be not ignited, is fometimes attracted by the magnet.

(c) This ore, pulverized and ftrewn upon hot coals, exhibits a kind of phofphoric appearance, which is light and momentary ; but

but when expofed to fire alone in a clofe
crucible, it quickly liquefies, and perforates
the bottom. This effect is occafioned by
the calcareous earth in the ore diffolving
the filiceous and argillaceous earth of the
veffel: thefe three, when mixed, eafily flow,
and befides, the calxes, both of iron and
manganefe, which are here prefent, promote
the vitrification very much.

(D) The powder, let fall into nitre,
fufed and ignited, fhews no diftinct detona-
tion, but a crackling is heard.

(E) I have attempted the reduction of
thefe ores by many different ways, but it is
only neceffary to mention thofe which are
particularly ufeful in the extraction of
iron.

The firft, moft fimple, and in many cafes
the beft, is this : — the bottom of a cru-
cible is covered, to the thicknefs of about
half an inch, with powdered charcoal ; this
powder is moiftened with water, mixed
with a fmall portion of argillaceous earth,
fo that upon compreffion the particles may
the better adhere together, and to the cru-
cible ; the fides are lined in the fame way,
but thinly. The fuperficies of the ftratum
ought to be rather concave, fo as to receive
in the lower part 100 of pulverized ore, co-
vered with calcined borax ; for that which
ftill retains the water of cryftallization up-
on boiling, difperfes many particles of the
ore ; finally, another crucible is to be in-

O 2   verted,

verted, and luted on, and the whole expofed to a proper fire.

The fecond method is this :—100 of the ore, mixed with an equal weight of mineral fluor, and half of apyrous clay, is put into a crucible, prepared after the manner above defcribed, and treated in the fame way, but without the addition of borax.

The third is directed by D. Scheffer :—to 1 part of ore are added 1 of tartar, 1 of charcoal-duft, 1 of glafs, 1 of white, and 2 of black flux ; the mixture is put into a crucible prepared without lining, and fhut as before.

The fourth, which has been long in ufe, is defcribed by Snack, and is preferred to all others by D. A. Swab, although it is very complex :—to 100 of the ore are added an equal weight, or 100 of fal ammoniac, 100 of tartar, 100 of glafs gall, 50 of borax, 50 of charcoal-duft, and of black flux 200 ; the mixture, put into an unprepared crucible, is covered with common falt, and, being covered, expofed to the fire.

In order to compare thefe different methods, with refpect to the white ore of iron, I treated different portions of it according to all the different methods, and that without previous calcination, which in this inftance is of no effect. That which I tried was a fpathous fruftum, not yet injured by calcination, brought from Eifenartz, in Upper Stiria :

Of

	lb.
Of this 100, according to the firſt me- thod, yielded of a regulus nearly of the ſplendor of ſilver - - - -	42
According to the ſecond, of a regulus of an aſh colour - - - -	39
By the third, a regulus of an aſh colour, but nearly cryſtallized on the ſur- face - - - - -	29½
By the fourth, of a regulus almoſt white and ſplendid - - -	36

I found nearly the ſame progreſſion to hold
with the ore of Naſſau, and with the other
ores, examined in the ſame way : in general
the weight of the regulus never attains to
50, but is often 30, 20, 10, nay even ſome-
times no more than 2, though the ore has
been made black by roaſting, and is at-
tracted by the magnet ; but hereafter it will
be demonſtrated that the blackneſs by fire
is not occaſioned by the iron, but by man-
ganeſe. The pureſt calcareous ſtones are
ſeldom entirely without iron. The clear-
eſt Iceland ſpar grows red by long calcina-
tion ; and even by the humid way yields its
metal to phlogiſticated alkali.

The ores which are ſo poor as not to yield
a regulus without difficulty, are uſually
brought to that ſtate by a ſmall quantity of
white arſenic, or rather of litharge ; for by
this method the ſcoria is made thinner, and
the ſmall globules permitted to ſubſide and
collect.

O 3   § VI. Pro=

§ VI. *Properties of these Ores, examined by the humid Way.*

(A) The white ores of iron effervesce indeed with acids, but in general more weakly than the calcareous stones; and sometimes no motion is observed, unless pulverization and heat be both employed. That calcareous earth is present will appear from what follows : but the reason why it only effervesces slowly, is to be sought partly in its proportion, and partly in its intimate connection with the other principles.

(B) All those acids which are usually called mineral dissolve this ore, if it be well pulverized, and a due degree of heat applied. The solution made by vitriolic or marine acid is generally of a yellow green; that by the nitrous of a red or yellow brown; the marine acid dissolves it sooner than the rest : these colours vary a little, in proportion to the quantity of metallic parts. Sometimes a brown redness at first appears, which then vanishes, but sometimes persists, unless sugar, or some substance rich in phlogiston, be added.

Almost always somewhat remains undissolved, which yet, upon examination, appears to be of a different nature. I have frequently seen grains of schoerl, zeolith, quartz, mica, nay fibres of asbestos intermixed : but these are foreign matters, which,

which, although they fometimes form above
0,2 of the mafs, yet are not a neceffary com-
ponent part of the ore.

The folution made by vitriolic acid, upon
evaporation yields green martial cryftals;
and that made in marine acid, without heat,
fometimes by fpontaneous evaporation con-
cretes into fpathaceous forms, compofed of
hollow pyramids.

(c) During the folution an elaftic va-
pour efcapes, which, when extricated by
vitriolic or marine acid, is not inflammable,
even although the crude ore be attracted
by the magnet.

The quantity of water is eafily difcovered
by performing the operation in a large bot-
tle, clofed fo as to give exit to the elaf-
tic fluid, but not to the moifture; for the
diminution of weight in this cafe indi-
cates only the volatile aerial fluid, whereas
the lofs fuffered during calcination fhews
the weight both of the elaftic fluid and of
the water.

(D) As the various qualities above men-
tioned indicate the prefence of lime, I at-
tempted to feparate it in the following
way :—let a portion of the pulverized and
calcined ore weighed, be put into diluted
nitrous acid, and let the mixture be fhaken
for a quarter of an hour; after which let the
powder be collected on a filter, and the clear
liquor precipitated with aerated fixed alkali:
by this method a white fediment was ob-
tained,

tained, which upon examination fhewed all the properties of lime. I employed the cal-cined mineral, and the nitrous acid, left any thing metallic fhould be taken up during the fhort agitation, otherwife the end might be anfwered by the marine acid; but then it is neceffary, in evaporating the folu-tion to drynefs, to expofe it to a more in-tenfe heat, that the diffolved metal may be fpoiled of its menftruum, for the lime retains the menftruum more obftinately : hence, after this operation, the falited lime may be elixated from the refiduum by wa-ter, and precipitated by an alkali.

The weight of lime varies much; in fome ores I found a few hundredths ; in the fpa-thaceous kind about 0,1 confifts of lime, in others 0,5, but it is never entirely wanting.

(E) Into a folution of the ore made with the pureft marine acid, I poured a few drops of folution of terra ponderofa in the fame menftruum, but the tranfparency was not in the leaft difturbed ; from whence I con-clude, that there is no vitriolic acid pre-fent.

(F) The fame is true of the marine acid ; for I examined the fmall portion of water expelled folely by heat in the diftillation (§ v. B), and could not, even by paper ting-ed with turnfole, difcover any traces of an acid : I alfo poured concentrated vitriolic acid upon the powdered ore in a retort, and into the receiver a fmall quantity of diftilled

water,

water, as water very greedily attracts the marine acid in a ftate of vapour; but neither by the fmell, by any vifible vapour, nor by precipitants, could I difcover the fmalleft figns of a mineral acid, unlefs the heat was increafed to fuch a degree as to force over fome of the vitriolic acid. The water in the receiver was not at all difturbed by folution of filver, although, upon touching it with the end of a glafs rod wet with marine acid, the filver was immediately precipitated, and a white fediment feparated.

I conclude therefore with reafon, that the vitriolic and marine acids, if they fometimes happen to be prefent, do not belong to the proper compofition of the ore; and, in fact, how could the aerial acid exift together with thefe, being eafily expelled by either of them?—and how could the marine acid, which with lime and iron forms deliquefcent falts, in this cafe form with them an ore which not only remains dry in the open air, but even undergoes fpontaneous calcination?

§ vii. *Principal Properties of Manganefe.*

I have hitherto frequently named manganefe, and mentioned feveral circumftances which cannot be properly underftood without previoufly confidering its nature. It is neceffary therefore, before we proceed further, to defcribe the principal properties of
this

this fubftance, fo far as they have hitherto been difcovered.

(A) The mineral fubftance which is called black, or glafs-makers, magnefia, is fcarcely any thing more than the calx of a new metal.

It is many years fince I began to fufpect that fome metal, different from all thofe formerly known, lay concealed in magnefium, being partly led to this opinion by the fpecific gravity, partly by its property of tinging glafs, and partly by its feparating from menftrua on the addition of phlogifticated alkali, a circumftance which takes place with all the metals, but not with any earth. In the mean time I attempted the reduction of it in various ways, but in vain ; for either the whole mafs ran into fcoriæ, or I obtained only difcrete fphærical atoms, fo much loaded with iron as to be magnetic. On account of its being fo difficult of fufion, I at firft imagined it had fome affinity with platina : at length Mr. Gahn, without knowing any thing of my experiments, fucceeded in obtaining larger pieces of regulus by means of a moft intenfe heat ; and Mr. Scheele, in 1774, publifhed feveral curious facts relating to manganefe.——The principal things refulting from the experiments of thefe gentlemen, and from my own, fhall be the fubject of the following pages.

7

(B) The

(B) The reduction is effected in the fol-
lowing way :—a certain quantity of manga-
nefe, formed with oil or water into a ball,
is put into a crucible prepared with char-
coal-duft, as before defcribed (§ v. E), the
empty fpace is then filled up with char-
coal-duft ; another crucible is inverted by
way of cover, and luted, and the whole ap-
paratus expofed to the moft intenfe heat
which the laboratory can produce, for an
hour, or more if neceffary. The veffels be-
ing cooled and emptied, a regulus is form-
ed, fometimes confifting of many pieces,
which, collected, in fome cafes amount to
0,3 of the manganefe.

If the fire be weaker than neceffary, either
no reduction takes place, or the metallic
particles are difcrete, not being fo fufed as
to run properly together. If during the
operation the crucible falls, fo that the me-
tal fhall touch the naked fide of the veffel,
vitrification is inevitable.

(c) The metal obtained, which I call
manganefe, is about the fpecific gravity
6,850.

The furface is generally brown, and the
larger pieces of regulus are fcarce ever found
globular, but knotty and irregular, which,
no doubt, is owing to the difficulty of fufion,
in which it feems to exceed even forged
iron.

Being harder than iron, it breaks under
the hammer : the fracture is irregular and
                                    rough,

rough, with a fort of whitifh metallic fplen-
dor, which foon fpontaneoufly grows brown :
even the fmaller pieces are not magnetic ;
but the powder is generally obedient to the
magnet, though the admixture of iron be
avoided with all poffible care.

Some fmall pieces, expofed to the fire in
an Heffian crucible, in a blaft-furnace, and
kept there for twenty minutes, yielded a yel-
lowifh brown glafs, and a fmall globule of
iron. Here a remarkable difference between
the two metals is obferved, the manganefe
vitrifies, the iron perfifts, and is formed in-
to· a regulus.

The regulus, when well fufed, generally
perfifts in a dry place, but fometimes under-
goes fpontaneous calcination, and falls into
a brownifh black powder, which is found
fomewhat heavier than the perfect metal ;
yet, when frefh, contains fo much phlogif-
ton as to produce inflammable air, on folu-
tion in vitriolic acid : this phlogifton it
lofes by time. The caufe of this fpon-
taneous refolution is not yet fufficiently ex-
plained ; but it appears very probable, that,
on account of the weaknefs of the fire, the
particles fometimes coalefce fo imperfectly,
that when the dephlogiftication again begins,
they eafily lofe their mutual connection :
moifture, but particularly the accefs of aerial
acid, affifts this operation. A fmall piece,
put into a dry bottle well corked, remained
perfect for the fpace of fix months, but
afterwards,

afterwards, expofed to the open air of a chamber for two days, contracted a brown-nefs on its furface, together with fo much friability as to crumble between the fingers : the internal parts, however, retained an ob-fcure metallic fplendor, which difappeared in a few hours ;—a piece more fully im-pregnated with iron refifts the action of the air better.

(D) It melts readily with other metals, pure mercury excepted. Copper, united with a certain quantity of it, is extremely malleable ; but upon the furface of this mixture, when polifhed, fcarce any traces of the red colour are to be feen : this mix-ture fometimes by age produces a green ef-florefcence. Tin very eafily unites with manganefe ; but zinc not without much difficulty, perhaps on account of its vola-tile and inflammable nature. White arfenic adheres to it, and by means of phlogifton reduces it to a metallic form.

(E) Manganefe, calcined by fire, yields a blackifh calx ; but if the ignition be con-tinued for twelve days it acquires a dark green colour ; fometimes alfo it produces a white or a red calx, of both which we fhall treat feparately (G). The black calx retains a very fmall portion of phlogifton, but the white abounds with it fo much that it is foluble in acids.

All thefe varieties, in a common cruci-ble, by means of a fufficient degree of fire,

run

run into a yellowifh red glafs, which is pellucid, unlefs too great a degree of thick-nefs renders it impervious to the rays of light.

The black calx of manganefe by a pecu-liar energy, when mixed with other fub-ftances, attracts phlogifton, and exhibits fe-veral remarkable phænomena both by fire and folution; the chief of which we fhall confider, beginning with thofe which occur in fufion.

(f) In order to difcover the genuine ha-bits of this fubftance, we muft employ the blow-pipe; for, by means of this inftru-ment, we can diftinctly fee all the fuccef-five changes occafioned by fire, from the beginning to the end.

Let a globule of microcofmic falt be fufed upon the charcoal, and to it be added a fmall portion of the black calx; let this mixture be fufed, by means of the interior blue flame, for a few minutes, and it will yield a bluifh red pellucid glafs; but if the quantity of calx be greater, it is of a rich red. Let it be again fufed, but for a longer time, and we fhall find the tinge totally deftroyed. Let the globule, which is now colourlefs, be foftened by the exterior flame, and the colour quickly returns, and may be again difcharged by continued fufion. The fmall-eft particle of nitre too, added to the glafs, inftantly reftores the red colour; whereas fulphur, and the falts containing vitriolic acid,

acid, contribute to difcharge it; as alfo do the metallic calxes, although thefe, in proper quantity, communicate each its own particular colour.

The glafs globule, after being deprived of all colour, if fufed in a filver fpoon recovers its rednefs, which it retains notwithftanding a long continued fufion; inflammable additaments indeed extinguifh the colour, but this is eafily reftored by fufion, nor can it again be difcharged without a new addition.

Thefe changes are agreeable to the eye, and of themfelves very remarkable: upon confidering the whole, it will readily appear that the caufe of them is to be fought in the different quantities of phlogifton. Let us firft examine the moft fimple cafe:— the globule of microcofmic falt fufed, confifts of the phofphoric acid only, partly faturated with mineral alkali; the difengaged part muft therefore necefarily attract phlogifton from the ignited charcoal, which is again taken from it by the calx of the manganefe: now this calx, by a certain degree of phlogifton, is reduced to fuch a ftate that it exhibits no tinge, almoft in the fame manner as the feven primitive colours when collected form the light of day, at once white and tranfparent; now, whatever dephlogifticates the glafs, deprived of this tinge, reftores the rednefs, and this is effected by the nitre and the exterior flame.

Thefe

These changes cannot take place in the filver fpoon, becaufe in this cafe the fupport does not fupply any phlogifton, and therefore the colourlefs globule fufed upon it is quickly deprived of the quantity of phlogifton it had before imbibed by the furrounding air—a lofs which in this inftance cannot be repaired, and therefore the globule continues red.

The additaments capable of deftroying the colour are fuch as naturally contain phlogifton, fuch as fulphur and white arfenic; or at leaft fuch as eafily take it up from the coal, fuch as gypfum and the other falts containing vitriolic acid, which thus readily run into fulphur. The metallic calxes too are of fuch a nature that they take phlogifton from burning charcoal, which they are immediately obliged to give up to the calx by means of its fuperior attraction.

The phænomena above defcribed and explained alfo take place with borax, but with fome difference: the colour with microcofmic falt is a bluifh red; that with an equal quantity of borax, a yellowifh red; but in both cafes, by faturation, the fame intenfe red is obtained. By fufion upon charcoal too the tinge is not deftroyed fo foon in the latter cafe, as borax attracts phlogifton with lefs force than the phofphoric acid does.

If a fmall quantity of calx of manganefe be added to an alkali, either vegetable or mineral, fufed in a filver fpoon, and the fire
continued

continued for a few minutes, the globule
foon becomes of a whitiſh blue; or, if any
iron be preſent, it acquires a green tinge; by
a larger quantity the colour is made more
intenſe, even ſo far as to appear nearly
black; but the maſs fuſes flowly, and, by
being marked with ſpots, ſhews an unequal
diſtribution. If to the fuſed maſs be added
either powder of charcoal or white arſenic,
the calx of the manganeſe is phlogiſticated
and the colours periſh; hence it appears
why common cryſtalline glaſs grows red by
the admixture of manganeſe; but if the al-
kaline ſalt prevails in it, it contraᴄts a violet
colour.

Nitre fuſed in the ſpoon flows about; but,
added in ſmall quantities to the alkaline
ſalt, does not deſtroy its globular figure: in
this caſe the colour is changed to green by
the addition of a ſmall quantity of calx of
manganeſe, on account of the calcined iron
preſent in the blue maſs.

Many of theſe changes take place in a
crucible, but not all: the red glaſs indeed,
upon the addition of powdered charcoal, ef-
ferveſces, and is deprived of its tinge; but
the ſalts containing vitriolic acid, and the
ignoble metallic calxes (except white arſe-
nic, which eaſily yields its phlogiſton) are
of no effeᴄt; for although the veſſel be red
hot, neither the acid nor the calxes are
thereby ſufficiently loaded with phlogiſton,
and that portion which they naturally con-

tain, in this cafe is not feparated; the con-
tact of ignited coal is neceffary.

Thefe things being known, it will not be
difficult to explain the ufe of manganefe in
the purification of glafs; for the iron, which
contaminates a vaft number of bodies, ad-
heres not only to the alkali, but to the fili-
ceous earth of which the glafs is compofed.
Now this metal, in order to enter the tex-
ture of glafs, muft be deprived of a certain
quantity of phlogifton; the great quantity,
however, of that principle with which it is
capable of entering glafs, produces a green
colour in the fame way, as by folution in
acids (particularly the vitriolic) it produces
a green vitriol: yet this falt, on being re-
peatedly diffolved, fucceffively lofes more
and more of its phlogifton, for that reafon
grows pale, and at length is changed into a
brownifh red lixivium, which refufes to
cryftallize. If now fo great a portion of
manganefe be added by fufion to glafs, that
on the one hand the phlogifton occafioning
the green colour may be abforbed, and on
the other by means of that phlogifton the
calx be deprived of all colour, we fhall have
a glafs colourlefs as water. Too great a
proportion of manganefe will impart its
own colour, too fmall a one will leave a part
of the original green in the glafs: the lat-
ter excefs, however, is preferable to the for-
mer, for a very flight degree of green is not
perceptible in glafs, unlefs when it is fo hot
as

as almoſt to liquefy; and this, upon cooling, becomes again entirely inviſible. But the iron, if too much dephlogiſticated, communicates a yellow hue, which cannot be removed by the calx of manganeſe, but like the green when weak, can only be perceived in the glaſs while hot.

(G) The habits of manganeſe, examined by ſolution, confirm and illuſtrate the former experiments.

The vitriolic acid, even when concentrated, attacks manganeſe in its metallic form, but much better when diluted with double or triple the quantity of water: innumerable bubbles ariſe, which when collected are found to be inflammable. It is diſſolved more ſlowly than iron, and leaves behind a black ſpongy ſubſtance, of the ſame figure as the metal; a ſmell is perceived ſimilar to that occaſioned by marine acid with iron: the ſolution is colourleſs, like pure water; and upon evaporation depoſits very bitter ſpathous cryſtals, which are clear and colourleſs; but on the addition of alkali lets fall a white precipitate, which we formerly called the white calx of manganeſe, and is now to be more accurately examined.

It readily appears that this white calx of manganeſe, or more properly white aerated manganeſe, is not ſaturated with phlogiſton, as it wants the reguline form; and that regulus of manganeſe during ſolution is deprived of a portion of its phlogiſton, is the leſs

P 2   doubtful,

doubtful, as it is certain that during that pro-
cefs inflammable air is generated. This calx
however retains precifely that quantity which
is neceffary to render it foluble in acids; and
when this portion is diffipated by a white
heat in open air, the calx grows black, and
affumes the properties of the black calx,
which we have been confidering. Here we
muft obferve, that a folution of manganefe,
much diluted, although with aerated alkali
it affords a white precipitate, yet with the
cauftic alkali yields either at once a brown
calx, or one which foon grows black in the
open air; the reafon is this :—aerated alkali
yields the aerial acid to the falling calx, as
is eafily feen from the increafe of weight,
the effervefcence of the precipitate with
acids, and by pneumatic diftillation : but
in this cafe the acids fix the quantity of
phlogifton neceffary to folution, as is feen
from hence, that the pure air contained in
the atmofphere or in water, although ex-
tremely greedy of this principle, is yet in
this cafe not able to feparate it. But the
white calx is eafily taken up by all acids,
and does not at all tinge the menftruum,
unlefs it be fenfibly mixed with iron : it
follows naturally that the calx, precipitated
by aerated alkali, fhould effervefce with
acids ; it is alfo to be obferved, that the
whitenefs is the more perfect as the quantity
of iron is lefs, as this foreign admixture ful-
lies the colour by a yellow or a brown.

We

We now proceed to the calcined black manganefe: this, when either old or well calcined, is only taken up in fmall quantity by boiling in vitriolic acid; neverthelefs, if the menftruum be added by fucceffive portions, each of which renders a little foluble, it may be gradually faturated; and then, with aerated alkali, depofits a white calx: this feems to indicate that the calx, though dephlogifticated, yet poffeffes a fmall quantity of phlogifton, which is infufficient for the folution of the whole; notwithftanding which, the menftruum may be fufficiently faturated by fuch particles as lie next adjoining to it: thefe, by means of the acid, are capable of taking the neceffary phlogifton from the more remote, if the number of them be fufficiently great to fupply the quantity of phlogifton which is requifite for folution.

A fingular tranflation we have already found to take place in the via ficca; and that the fame is the cafe, the circumftances now to be related will put beyond all doubt:—the calx thus exhaufted altogether rejects the vitriolic acid, unlefs fome fubftance charged with phlogifton be added, which phlogifton is, by means of the acid, transferred to the calx; thus, upon the addition of fugar, honey, gum, or other fuitable fubftances, the folution may be promoted and compleated. Such of thofe fubftances as upon the abftraction of their phlogifton

perifh

perish (namely organic bodies) leave no other vestige of themselves in the solution than the phlogistication above mentioned. A similar effect is also produced by the metals, not only the imperfect, but, what is very extraordinary, even by gold itself: this especially takes place in the marine acid, but in all cases the metallic calxes are easily found in the solution. We have said that phlogiston is easily transferred, by means of the acids, to the black calx; and that this, when loaded with plogiston in proper quantity, is dissolved; and this we have affirmed not without reason, for the calx, when boiled with sugar dissolved in water, is not supplied with phlogiston, nor is the sugar changed, but remains complete; and when it is separated by lotion the calx is found insoluble as before: but if an acid be also added, by its means the calx takes up quickly as much phlogiston as is necessary to make it soluble; nay, the phlogisticated vitriolic acid, when poured upon the calx, soon loses its smell, and dissolves it readily without any assistance.

Another method of solution has also been found out, which clearly shews the great attractive force this calx possesses with respect to phlogiston: thus, let the vitriolic acid be drawn off from the black calx several times with an heat approaching to ignition, in a glass vessel, either open or shut; after each operation let the soluble part be elixated with water, and at length nothing will

will remain : from whence then is derived
the phlogifton neceffary for folution?—I an-
fwer, from the decompofition of the matter
of heat, which confifts of pure air, joined to
a determinate quantity of phlogifton. In
order to fhew that this is not bare conjec-
ture, let the operation be performed in a
clofe veffel to which is adapted a pneumatic
apparatus ; and towards the clofe of the pro-
cefs pure air is copioufly produced, which
is extricated while the phlogifton is uniting
with the calcined manganefe. The calx is
indeed of itfelf capable of decompofing the
heat, but cannot be rendered foluble without
acids : if the acid, a little diluted, be drawn
off only to drynefs from one half its weight
of black calx, water is able to take up by
elixation upwards of one fourth of the
calx : this water is of a beautiful red, and
on due evaporation yields cryftals of the
fame colour ; this tinge indicates a deficien-
cy of phlogifton, a deficiency which, as has
been already faid, may be fupplied either by
continuing the abftraction to ignition, or by
fome fuitable phlogiftic additaments.

We have hitherto only confidered the
white and the black calx ; it is proper now
to beftow fome attention upon the other va-
rieties : that which is produced by the fpon-
taneous calcination of the regulus is at firft
of a dufky colour, but in the open air grows
more brown ; and in about fourteen days the
weight is increafed by 0,35, and is again

<div align="center">P 4</div> diminifhed

diminished a few hundredths, on exposure to heat. The humidity which had been attracted from the atmosphere being now expelled, this calx, in proportion as it is more newly made, and less exposed to fire, is the richer in phlogiston, and is the more quickly dissolved in vitriolic acid, with which it produces a bluish red colour: this elegant tincture, gently precipitated by means of aerated alkali, at length shews some red particles subsiding, which yet, collected on a filter, grow brown. It appears very probable that the red calx forms a sort of medium between the black and the white, being more soluble than one, and less soluble than the other; and that the colour indicates the imperfect state of the solution, for by the addition of sugar it is discharged in a few minutes: to this class, doubtless, belong the red and brown ores of manganese. The particles enveloped in transparent matrices afford very beautiful specimens, more or less pellucid: thus the red spathous ore which is got at Klapperud, in Dalia, is found filled with zeolith; so that a small piece, gradually put into an acid, is spoiled of the red calx, from the surface successively inwards to the center, though the original form and magnitude remain: the remainder, upon examination, is found totally siliceous, for the argillaceous and calcareous parts of the zeolith matrix are extracted by the acid, together with the calcined manganese.

<div style="text-align: right">Both</div>

Both the red and the colourless calx of manganese are precipitated by a phlogisticated alkali of a whitish yellow, unless the iron be superabundant.

It has already been observed that the black calx of manganese grows green in a red heat, which was first remarked by the celebrated Rinman, upon making the experiment on a species of black calx of manganese, which must yet be particularly distinguished ; for though it consists for the most part of a black calx, yet it contains a number of heterogeneous particles, such as calcareous and siliceous earth, and terra ponderosa, substances which are always mixed with the Swedish calx : this green calx is found concreted into loose grains, is made white by the vitriolic acid, and corroded into a subtile powder ; but very little is dissolved, even by the addition of sugar, nor is a red tinge ever produced.

Having thus spoken pretty fully of the vitriolic acid, let us now briefly consider the other acids.

The nitrous acid dissolves the regulus with a certain effervescence, occasioned by the generation of nitrous air ; yet a spongy, black, and friable body remains, resembling molybdæna in its properties, so far as the small quantity of the matter would permit experiments to be made. The other menstrua also exhibit a similar residuum ; the solution is always brown, which is occasioned by the
iron

iron adhering to the manganefe—it fcarcely acquires a red colour : the white calx is very readily taken up by the acid, during which operation the aerial acid is extricated, but no nitrous air appears. The faturated menftruum has the appearance of water, unlefs iron be prefent : the black calx is very fparingly diffolved, yet a faturation is effected by means of a large quantity of the calx—phlogiftic additaments complete the folution ; but thefe are not neceffary if the acid be employed in a phlogifticated ftate. In this cafe the decompofition of heat feems to have lefs effect, as the menftruum, being more volatile than the vitriolic acid, is diffipated by a lower degree of heat. The green calx is acted upon in the fame way as by the vitriolic acid : the folutions when pure depofit no folid cryftals, although the evaporation be conducted with the moft cautious flownefs.

Reguline manganefe is diffolved in the ufual manner by the marine acid, as is alfo the white calx ; nay, the black is taken up in the cold by this menftruum, and communicates to it a red colour. I had before conjectured that the red calx is richer in phlogifton than the black, an opinion which is confirmed by a circumftance which occurs here. Marine acid contains phlogifton as one of its conftituent principles ; and the black calx, by means of a fuperior attraction, feizes a part of this phlogifton, and acquires a certain degree of folubility : but this

this union is very flight, and may even be deftroyed by the fimple affufion of water : if, however, the red folution be expofed to a digefting heat for fome hours, an inteftine motion like an effervefcence takes place; the fmell of dephlogifticated acid is perceived, and the calcined manganefe is taken up in fuch a manner as to be only feparable by an alkali. The part of the acid which, by its phlogifton, has rendered the calx foluble, puts on the appearance of a red vapour, and flying off manifefts itfelf by a peculiar odour : if fugar be employed, the decompofition of the menftruum is not neceffary, nor is any fmell of aqua regia perceived ; other fuitable phlogiftic matters in the fame way effect the folution of the black calx ; nay, mercury itfelf, and even gold, neither of which yields directly to the marine acid, yet fupply calcined manganefe with their phlogifton ; and, being thus dephlogifticated, are diffolved in the menftruum along with it.

Salited manganefe fcarcely yields diftinct cryftals, but only a faline mafs, which attracts the moifture of the air : the precipitate by alkali is occafionally either white, yellow, or black.

As the fluor acid, united with manganefe, forms a falt difficult of folution, it is thence fufficiently obvious, that the folvent power of that acid is extremely weak ; for the particles, being furrounded by a faline cruft, are

freed

freed from the action of the menstruum,
yet, upon repeated additions, the acid may
be saturated. If fluorated volatile alkali be
added to a solution of manganese made in
another acid, instantly a double elective at-
traction takes place, and a fluorated man-
ganese falls to the bottom.

The same is true of the phosphoric acid.
The microcosmic salt, added to manganese
dissolved in another acid, by a double affini-
ty precipitates a phosphorated manganese.

The power of vinegar is weak, yet it dif-
solves the regulus in the way above describ-
ed, and may even be saturated with the black
calx, if that calx be added in large quanti-
ty. This combination yields no crystals;
and after evaporation quickly deliquefces
again.

Not only reguline manganese, but also the
black calx, is taken up by the acid of sugar;
but the saturated solution deposits a white
powder scarcely soluble in water, unless it be
sharpened by an acid. This salt grows black
in the fire, but on addition of the saccha-
rine acid, easily again acquires a milky co-
lour. Manganese is precipitated in the form
of crystalline atoms, by acid of sugar, from
its solution in vitriolic, nitrous, or marine
acid.

The acid of tartar, which is similar to
this, takes up the black calx even in the
cold, but the colour of the solution is a
reddish brown; however this tinge is dif-
charged

charged with effervefcence in a digefting heat; a part of the menftruum is therefore decompofed, and yields its phlogifton to the calx, as has been already obferved of the marine acid; befides, the tartarized vegetable alkali, added to any folution of manganefe, immediately throws down tartarized manganefe.

The circumftances already mentioned take place with the acid of lemons, which in this inftance poffeffes altogether the fame properties.

The weak aerial acid faturating water, attacks both the regulus and the black calx: the manganefe, thus diffolved, if not mixed with iron, feparates in the form of a floating white pellicle; by tincture of galls, or an alkali, it is precipitated white: if it is the regulus which has been employed, a peculiar fmell, refembling that of burning fat, is perceived.

A very minute portion of the black calx, added to an alkali in fufion, immediately tinges it of an elegant blue, or fometimes a green colour, if iron be prefent; hence it is that pot-afhes are fometimes found variegated with blue or green: the green folution in a clofe veffel gradually depofits its iron, and then, the yellow being difcharged, it becomes blue: expofed to the open air, the alkali attracts the aerial acid, and the black calx is depofited, a depofition which is more quickly effected by a few drops of
a ftronger

a ftronger acid, or even by a large quantity of water; by this laft the folution grows firft violet, then red, and at length all colour vanifhes, the black particles which before had been red being depofited: thefe particles, while red, had been equally difperfed through the clear mafs; but being more completely deprived of their phlogifton, at length grow black.

(H) Eight parts of calcined manganefe, by a gentle heat in a glafs retort, take up three of fulphur, and produce a yellowifh green mafs, which is acted upon by acids, diffolving the metal with effervefcence and an hepatic odour: the fulphur which remains after the generation of the hepatic air may be collected on a filter.

Reguline manganefe appears to reject fulphur.

(I) Thefe properties evidently fhew, that manganefe differs confiderably from all metals hitherto known; in fufibility and colour it fomewhat refembles iron; in its ftrength of attraction, fpecific gravity, and in producing a colourlefs vitriol, it approaches to zinc; but in other properties is totally different.

Iron is malleable and magnetic when it retains the greateft poffible quantity of phlogifton: during folution in acids it exhibits a green colour, but upon a greater dephlogiftication it grows pale; and the laft lixivium, which refufes to cryftallize, puts on

10   a reddifh

reddifh brown appearance. The vitriol of his metal, diffolved in water, is decompofed fpontaneoufly in an open veffel, and feparates in ochre—this depofition is accelerated by heat: the calx depofited is of a reddifh brown, or at leaft reducible to that colour by a due degree of heat.

Zinc is of a white colour, eafily fufible, and inflammable by ignition in open veffels, and burns with a moft elegant flame, fending forth white flowers; but in clofe veffels the metal, being volatile, rifes by the force of the fire: it forms with copper a yellow compound, which, when the relative quantities are properly adjufted, refembles gold: it is eafily diffolved in all the acids, whether it be reguline or calcined, and forms a colourlefs folution: it yields a white calx, which is not rendered black by a red heat of fome minutes: and it never tinges glafs red: thefe, and its other properties, readily diftinguifh it from manganefe. The entire habit of the latter with phlogifton is fo fingular, that it cannot eafily be confounded with the other metals; for what metallic calx, except the black calx of manganefe, is able to decompound marine acid and volatile alkali, nay to feparate the phlogifton even from gold itfelf?— What other, when deprived of its phlogifton, can form a blue folution with alkaline falts, and a red with acids, which it again lofes by means of phlogiftic additaments?—

What

What other is there which, by the difference in the quantity of phlogifton, can exhibit colours fo various and fo diftinct, namely, white, red, green, and black ? It is generally thought that black calxes contain the greateft quantity of phlogifton, but in this cafe the black contains leaft of it.

Befides, manganefe, though tortured in many different ways, could not be changed into iron or zinc, or any other known metal, but obftinately retained its own properties ; therefore, until experiments, free from the leaft ambiguity, fhall have fhewn that this is derived from other metals, it muft be confidered as a diftinct metallic fubftance, unlefs we wifh to overturn the certainty of natural philofophy altogether, by indulging fallacious conjectures. The difficulty with which the martial inquinament is feparated, indicates no more than the exiftence of a very intimate union. The regulus eliquated from the black manganefe of Sweden, expofed in an Heffian crucible for a quarter of an hour (without any additament) to a violent heat, loft 0,33, which had feparated in the form of a brownifh yellow fcoria. The regulus was not yet magnetic ; and, by the addition of fugar, the acids extracted pure calx of manganefe ; at leaft, with phlogifticated alkali, no traces of Pruffian blue could be difcovered. The remainder of the regulus weighed 67 lb. ; and, upon repeating the

operation,

operation, the part which was magnetic weighed only 25 lb. and the black fcoria was found contaminated a little with iron. This regulus, fufed again, yielded only 17 lb. and diffolved in acids, by the addition of phlogifticated alkali, both white and blue particles were depofited, the former of which appeared moft numerous ; fo that we may conclude, that in 100 parts of manganefe there are not prefent, of common iron, more than 0,08.

The method by which the quantity of iron may be accurately examined, will be defcribed § VIII. B.

§ VIII. *Method by which Manganefe, when mixed with Iron, may be diftinguifhed and feparated.*

The ores of iron and of manganefe are very frequently loaded with both metals ; and although the iron ores are often found without manganefe, yet thofe of the latter are fcarcely ever free from the former. The alxes of thefe two metals are alfo frequently found together in the vegetable kingdom.

(A) In order to difcover the prefence of manganefe in iron quickly and eafily, the blow-pipe may be employed in the manner above defcribed (§ IV.) ; but no rednefs appears, if a particle of complete metal be added to the falt in fufion, as the tinge is

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deftroyed by the phlogifton of the iron
(§ VI. F and G). The purpofe is generally
better anfwered by a fmall portion of the
metal well calcined; but upon charcoal the
metallic calx attracts phlogifton from the
fupport, therefore the fufion muft either
be performed in a filver fpoon, or elfe the
red colour muft be induced by a fmall piece
of nitre. A perfon ufed to the procefs
will eafily know the prefence of manganefe,
and even be able, from the phænomena, to
judge of its quantity.

In a crucible too, the prefence of man-
ganefe is difcovered without difficulty. To
a piece of iron, weighing a few affay pounds,
and made red hot, let there be added about
five times the quantity of cryftallized nitre;
and let the fame quantity be again added
when the effervefcence has ceafed : if any
manganefe be prefent, a green ring will be
found round the middle of the infide of the
crucible ; if the quantity be confiderable,
it will not be neceffary to add the nitre
a fecond time ;—the crucible muft be re-
moved from the fire while the mafs is red
hot.

(B) Let a determined weight of the iron
fufpected to contain manganefe be diffolved in
a large quantity of nitrous acid, let it then
be evaporated to drynefs, and at length made
red hot : let the refiduum be weighed, and
put into diluted nitrous acid, together with
a fmall piece of fugar ; and if any manganefe

2   be

be prefent, after a few hours the menftruum, when faturated with aerated alkali, will yield a white metallic calx, which may be thus totally abftracted : let the remainder, which is totally deprived of manganefe, be elixated, dried to ignition, and finally again weighed—the difference of weight, before and after the extraction, will fhew the quantity of calcined manganefe ; and this being given, the correfponding quantity of reguline manganefe is eafily determined, as that metal gains 0,33 by calcination. The folution itfelf alfo, precipitated by a fixed alkali, affords a white calx, the knowledge of which eafily determines the quantity of the reguline manganefe ; for experiments fhew that 100 parts of this metal diffolved, yield 180 of white calx.

The white calx thus obtained is feldom entirely free from iron, as it is very difficult to deprive that metal fo far of its phlogifton, that the nitrous acid, efpecially when phlogifticated, cannot take up fome portion of it : but if the white calx, obtained as above, be well calcined, and again diffolved in nitrous acid, by means of the addition of fugar, the iron remains for the moft part undiffolved ; at the beginning too, the martial inquinament, being weaker in attractive power, may be precipitated by a few drops of volatile alkali.

Iron, contaminated with manganefe, if powdered and plunged into a folution of

Q 2   martial

martial vitriol, is gradually depurated; for, in virtue of its fuperior attraction, the acid feparates from the iron, and diffolves the manganefe.

§ IX. *Proximate Principles of the white Ores of Iron.*

Thefe things being premifed, we are enabled to judge properly of the compofition of our ores, namely, they always confift of lime, iron, and manganefe, but in proportions infinitely varied ; for we fhall pafs over in filence the foreign matters, which we have already mentioned as being fometimes prefent (§ vi. B).

(A) The prefence of lime is indicated by the effervefcence, more or lefs remarkable, occafioned by the pulverized ore (§ vi. A) ; by its occafioning an heat in water, when fufficiently burned ; by its feparating a cream (§ v. A) ; and by the whitifh opacity occafioned upon cooling, in the nitrous globules, when too much loaded with it (§ iv. B). Other circumftances tend alfo to prove the fame thing ; but the humid folution (§ vi. D) it is which puts the matter beyond doubt. If any portion of the metal fhould at the fame time enter the menftrua employed (which is generally the cafe) that part ought firft to be precipitated by phlogifticated alkali ; and afterwards the lime, by an aerated alkali.

(B) Of

(B) Of the prefence of iron there is no doubt ; the crude ore is fometimes attracted by the magnet, which is almoft always the cafe when it is burned ; but fometimes, even after burning, this property is concealed by the finalinefs of the quantity, the iron frequently not exceeding 0,02, which neverthelefs is difcovered in the folution by means of phlogifticated alkali. The quantity of metal is difcovered by reduction, either in the humid way or by fire, folution, and precipitation (§ v. E ; viii. B).

That iron, deprived of its metallic form, is prefent, eafily appears, for the ore is feldom magnetic before roafting ; nor on folution does it generate inflammable air, when the menftruum is vitriolic or nitrous acid : however, as the perfect ore yields without heat green folutions, except with the nitrous acid, and produces with the vitriolic acid a beautiful green falt, we may thence collect, that the deficiency of phlogifton is in this inftance not greater than in martial vitriol.

(c) The prefence of manganefe is indicated by the moft manifeft figns, and that even in the ftate of white calx, unlefs when injured by lapfe of time : thefe are, the blacknefs occafioned by calcination, either fpontaneous or produced by fire (§ iv. A ; vii. G) ; the habits, when examined by the blow-pipe (§ iv. vii. F) and by other experiments, both by fire (§ v. vii. A, F)

Q 3   and

and by the humid way (§ vi. viii. g). But what puts the matter entirely beyond doubt is, that the calx may be feparated, and feparately examined (§ viii. b). White calcined manganefe forms proportions of the whole mafs very unequal. From the regulus of Eifenartz, 42 lb. in weight, 24 of white manganefe is obtained (§ v. e) ; which weight alfo yields 13 lb. of regulus of manganefe ; the iron, therefore, is 42 — 13 = 29: and in 100 parts of this ore, of calcined iron, as in green vitriol, about 38, of aerated manganefe 24, and of aerated lime 38. The ore brought from the mountain, which in Sweden is called the weftern Silver Mountain, in the fame way yielded 22 of calcined iron, of white calcined manganefe 28, and of aerated lime 50.

§ x. *Ufe of the white Ores of Iron.*

It is well known to the fkilful in thofe matters, how excellent the fteel is which is produced by the white ores ; although that the foundation of this excellence is an admixture of manganefe has heretofore been unknown. In the reguli formerly eliquated (§ v. f.) the manganefe formed about one third, by which, not only the hardnefs was increafed, but a filver fplendor communicated. The beft proportions in mixing the metals muft be determined by various and repeated experiments.

Thefe

Thefe ores frequently contain iron in fuch fmall quantity that they cannot properly be dénominated from that metal ; one or two hundredths are certainly of no fuch confequence : in fuch the calcareous earth abounds, which confequently by roafting is converted into quick-lime, but is black or brown, on account of the dephlogiftication of the earthy bafe of the manganefe. A black calx of this kind is got in the neighbourhood of Upland ; this affords excellent mortar, which grows harder, and dries more quickly, than any other, even under water. This fuperior excellence is rather to be attributed to the manganefe than to the iron, as the calcareous ftones, deprived of manganefe, though containing the fame portion of iron as thofe of Lena, yet produce a mortar of a much inferior quality. We have calcareous ftones in many places of Sweden, which grow black on burning, and which doubtlefs poffefs the fame virtue.

We employ the black manganefe in glafshoufes for purifying glafs : how this acts has been already explained (§ VII. F). It is very probable that calcareous earth, loaded with manganefe, and deprived of iron, fuch as we have fpoken of for building, may be applied to the fame purpofe.

Q 4   DISSER-

DISSERTATION XX.

OF

NICKEL.

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§ 1. *Historical Introduction.*

THERE is found in the parts of Germany which abound in metals, an ore which is called *kupfer-nickel*, sometimes grey, but often of a reddish yellow colour, and polished. This name it probably first got and still retains from this circumstance, that although it has the appearance of containing copper, yet not the smallest particle of that metal can be extracted from it, even by fire. The first account we had of it was from V. Hierne, in a book published in 1694, written in the Swedish language, concerning the discovery of ores and other mineral substances.

Henckel

Henckel confiders it as a fpecies of cobalt
or arfenic, alloyed with copper, and Cramer
refers it to the arfenical or cupreous ores;
but neither they, nor any other perfon (as
they themfelves confefs) were ever able to
extract from it a fingle particle of copper.
Several other philofophers acquiefced in this
opinion, until that celebrated mineralogift
Mr. Cronftedt firft undertook an accurate
examination of this mineral, and by many
experiments, which were publifhed in the
years 1751 and 1754, fhewed that it con-
tained a new femimetal, to which he gave
the name of *nickel*.

Almoft all the Swedifh mineralogifts af-
terwards embraced this opinion, as alfo did
many others, although the old opinion was
not entirely deferted; for fome were led ra-
ther by vague conjecture and fpecious appear-
ance, than by fatisfactory experiment; and
Mr. Sage has lately attempted to eftablifh
the former theory by chemical reafonings
and experiments. In the acts of the Royal
Academy at Paris he defcribed an analyfis of
nickel which he had undertaken, and upon
this grounds an opinion that the new femi-
metal is compofed of cobalt mixed with
iron, arfenic, and copper.

In order to decide upon this fubject
many experiments are neceffary, and thefe I
undertook with a mind totally free from any
preconceived opinion; and though upon
this occafion the fcarcity of the mineral pre-
vented

vented me from entirely removing doubt, yet I truft that fo much of the truth has been laid open, that when a fufficient quantity of this fubftance can be obtained, it will be found no difficult matter to eftablifh the truth in the moft decifive manner.

§ 11. *Eliquation of the Regulus.*

In order to obtain the regulus of nickel, the ore muft be firft fubjected to roafting, during which a quantity of fulphur and arfenic, greater or lefs according to the nature of the ore, is expelled ; fo that it fometimes lofes upwards of half its weight, but frequently not above 0,3. This ore, though long and completely calcined, does not always acquire the fame colour, but in general becomes greener in proportion as it is more rich ; fometimes (efpecially if fuffered to lie at reft) its upper furface is covered with green vegetations, fomewhat of the form of coral, which are hard and fonorous.

Let a double or triple quantity of black flux be added to the roafted powder, and the mixture well fufed in a forge, in an open crucible, covered with common falt, according to the ufual method.

The veffel being broken, a metallic globule is found at the bottom, under the fcoriæ, which are brown or black, or fometimes even blue: the weight of the globule

amounts

mounts to 0,1, 0,2, or at the moft 0,5 of
he crude ore.

This, however, is far from being pure;
'or although the roafting be ever fo violent
and long continued, yet a confiderable quan-
ity of fulphur, but efpecially arfenic, ftill
remains concealed in the regulus, exclufive
of cobalt, and a great proportion of iron,
which laft is generally fo prevalent as to
make the regulus magnetic; and this varie-
ty of heterogeneous matter is the caufe why
the regulus varies much, not only in re-
fpect to its fracture, the polifhed furface of
which is either fmooth or lamellated, but
alfo in regard to its white colour, which is
more or lefs yellow or red.

It is obvious from hence how neceffary
it is to depurate the regulus, if we wifh to
judge rightly of its genuine nature and pro-
perties : I have therefore undertaken a great
variety of laborious proceffes for this pur-
pofe;—to defcribe them all circumftantially
would far exceed the limits of this Effay;
I fhall therefore only mention the moft re-
markable, and that concifely; for in writ-
ing to metallurgifts it is by no means necef-
fary to defcribe all the minute circumftances
attending an operation.

§ III. *The Regulus depurated by Calcination
and Scorification.*

In order to difcover the effect of repeated
calcinations and fcorifications, the following
experiments

experiments were made with a certain regu-
lus of nickel found in the Suabian collection
of the Upfal Academy, which had been eli-
quated by Mr. Cronftedt, and whofe fpeci-
fic gravity, taken by a very exact hydroftatic
balance, was to that of diftilled water as
7,4210 to 1,0000.

(A) Nine ounces reduced to powder were
expofed in feveral difhes, for fix hours, to an
exceedingly vehement heat, under the dome
of an affay furnace; by this the arfenic was
firft diffipated with a fœtid fmell; a fulphu-
reous odour was next perceived; afterwards
a quantity of white fmoke, without the gar-
lic fmell, which probably arofe from the
fublimation of the more dephlogifticated
arfenic: when the heaps were hot they began
to fwell, and green vegetations fprang out
from all the furface, refembling mofs, or the
filiform lichen; there remained at the bot-
tom a powder of a ferruginous afh-colour.
In this operation 0,13 were diffipated.

(B) Half an ounce of this calx, fufed in a
forge for four minutes, together with three
times its weight of black flux, yielded a re-
gulus the furface of which was reticulated,
all the areolæ being hexangular, with ex-
ceeding flender ftriæ, diverging from a tu-
berculated center: it weighed 0,73 of half
an ounce, was obedient to the magnet, and
when fcorified with borax left a blackifh
glafs.

(c) This

(c) This regulus being again roasted, first yielded a garlic smell, and after a visible inodorous fume, together with vegetations as before.

(d) The roasted powder being reduced by the black flux, and taken out of the vessel, a smell of arsenic was again perceived: the fusion was repeated with the calx and borax, and nothing appeared but some obscure signs of cobalt.

(e) The regulus of nickel, roasted a third time, yielded but little smell of arsenic; no vegetations appeared; and finally the metallic calx had rather a ferruginous than a green colour.

(f) After reduction in the fourth calcination nearly the same phænomena appeared.

(g) Reduction being performed with lime and borax, the regulus, when first fused, lost much of its iron, which adhered to the black scoriæ; it soon acquired an hyacinthine colour without any remarkable mixture of cobalt; it was now but little obedient to the magnet, and its specific gravity 7,0828.

(h) The regulus was again roasted (the fifth time); but upon the gradual addition of powdered charcoal to the dishes when red hot, a prodigious quantity of arsenic, which was before imperceptible, flew off in the form of smoke; for it is the nature of this semimetal, that unless there be present a certain quantity of phlogiston, with which

it

it may unite, it does not yield to the action of fire, but remains fixed. The powder was treated in this way, until no more smoke or garlic smell appeared, although charcoal was again added.

(I) On reduction a regulus was obtained of a lamellated and tenacious texture, which yet, when the vessel was removed from the fire, diffused an arsenical odour.

(K) The roasting was therefore repeated a sixth time, and continued for ten hours, and by powdered charcoal arsenic was expelled, distinguishable not by the sight but by the smell; the colour of the metallic calx was obscurely ferruginous, mixed with a green scarcely visible.

(L) The reduction being effected with equal parts of the white flux, lime, and borax, a regulus was obtained, semiductile, highly magnetic, and soluble in nitrous acid, to which it communicates a deep green colour; yet there remains a blackish mass which eludes the force of the menstruum, which afterwards grows white, and, set upon a burning coal, flies off without any remarkable arsenical smell.

(M) The regulus was then six times fused with lime and borax; the scoria hence arising resembled the hyacinth in colour, but a green metallic calx surrounded the regulus, which, as before, was obedient to the magnet, and, being semiductile, broke
                                        tenaciously,

tenaciously, that is, the broken part was rendered rough by extended threads.

(N) After all these roastings the regulus was exposed during fourteen hours to a very strong heat; after this powdered charcoal was added by degrees, without any dissipation of arsenic, or loss of weight: the colour of the roasted powder was ferruginous, with a very weak tinge of green.

(o) After reduction, a very small globule, still magnetic, was found among the scoriæ, which were much loaded with iron. Of this globule we shall speak more at large in § IV. I, &c.

§ IV. *Eliquation of the Regulus from the Ore of Los.*

The nickel ore which is got at the mines at Los, in Helfing, was examined and depurated in the following way:

(A) The roasting was performed in the usual way.

(B) As was also the reduction.

(c) The regulus was then calcined, and the powdered charcoal was added by degrees, until all the arsenical smoke had ceased, and the calx of nickel acquired a deep green colour.

(D) This being reduced, a magnetic regulus was obtained, which yet, when fused with lime and borax, was not obedient to
the

the magnet, and yielded a fcoria of a deep blue.

(E) Powder of charcoal was gradually added, during ten hours, to a regulus of this fort fufficiently calcined (if this be inftantly done, the reguline particles readily coalefce) by which means a quantity of arfenic was difperfed, and a ferruginous powder, of a colour approaching to green, remained.

(F) After reduction with the black flux, lime, and borax, the fcoriæ were tinged partly with iron, and partly too with the nickel;— the white regulus was ftrongly attracted by the magnet.

(G) But afterwards, though phlogifton was added abundantly to the mafs in the difhes, for the fpace of fourteen hours, yet neither fmoke nor fmell betrayed any fenfible diffipation of arfenic, nor was the weight diminifhed; but, on the contrary, it was increafed $\frac{1}{9}$ by the roafting;—the metallic ferruginous calx was fcarcely green.

(H) After the reduction the regulus was femiductile and magnetic.

(I) This, firft fufed with lime and borax, and afterwards united with that which was mentioned in the preceding (§ III. o) yielded a white femiductile regulus diftinct, with the colour of green calx, and hyacinthine fcoriæ.

(K) The fame regulus was fufed with fulphur, and one-half its weight of the mineralized

neralized mafs, imperfectly roafted, was united by fufion with a portion of the crude mineral; this fulphurated nickel, well calcined, and reduced with a double quantity of black flux, yielded a regulus obedient to the magnet, which was nearly as refractory in the fire as forged iron.

As fulphur has a ftrong attraction for nickel, I had hopes that this mineralizing fubftance, not being fufficient to faturate both the nickel and the iron, would defert the latter, and adhere to the former; by which means, the iron entering the fcoriæ might be eafily feparated. The following paragraph will fhew the effect of this conjecture.

§ v. *Nickel depurated by Sulphuration.*

(A) 800 parts of the regulus of Cronftedt (§ 111.) fufed with fulphur and a fmall quantity of borax, yielded a mineralized mafs of a reddifh yellow, amounting to 1700.

(B) One-half of this, when firft expofed to fire in a roafting difh, began to grow black, then the heat was increafed until vegetations arofe; the metallic calx now remaining weighed 652.

(c) This half, fufed with borax, and the other part not burned, yielded a fulphurated regulus of a whitifh yellow colour, in weight 1102.

(D) The fame regulus, by a calcination

which lasted for four hours, was first co-
vered with vegetations, and afterwards, up-
on the addition of powdered charcoal, dif-
fused a continued odour of arsenic ; the
weight of metallic calx, which was of a
dilute green, was 1038.

(E) After reduction, a whitish yellow
regulus was found, in weight equal to 594,
semiductile, highly magnetic, and, at the
same time, exceeding refractory.

(F) This was again fused with sulphur,
which being done, the weight was equal to
816 ; one-half of which, roasted to green-
nefs, united by means of fire with the other,
still sulphurated, and in weight 509, scarcely
obeyed the magnet. After a calcination of
four hours, during which, by means of
the phlogiston, much arsenic flew off, the
powder put on an ash-colour, a little green-
ish, in weight 569, which by reduction
yielded a regulus the surface of which was
red, and which, upon breaking, appeared
of a white ash-colour, very friable, equal to
452 ; the specific gravity of which was
7,1730.

(G) The regulus, mineralized a third
time with sulphur, was treated in the same
way as before with powder of charcoal, so
long as any vestiges of arsenic remained,
which required a vehement calcination for
twelve hours. The powder then remaining
was of an ash-green colour, and weighed
364 ; but the regulus obtained by means of
a reduction, effected by exposure to a most

3   violent

violent heat in a forge for three-quarters of an hour, was fo refractory that it only adhered imperfectly to the fcoriæ, which were of a diftinct hyacinthine colour; nor could it be reduced to a globule by the addition of borax, though urged by the fame vehemence of fire. The abfolute gravity of this regulus was 180, but its fpecific gravity 3,6666; and it not only adhered ftrongly to the magnet, but to any other piece of iron, nay the fmall pieces of it attracted one another; it was befides fo ductile, that from a globule, whofe diameter did not exceed one line, a plate of three lines in diameter and upwards might be obtained by the hammer: it was of a whitifh colour, mixed with a glittering kind of red: diffolved in volatile alkali, it yielded a blue colour, and in nitrous acid a full green.

One hundred parts of the fame regulus, beaten out into thin plates, after a calcination of four hours, were covered with a cruft in appearance martial, under which was a green powder, and within a nucleus, confifting of reguline particles unchanged: the weight was increafed by 5. The friable matter, reduced to powder, put on a brownifh green colour, and after a calcination of four hours more, concreted at the bottom in the form of a friable blackifh cruft, which was ftrongly magnetic, and weighed 100; the cruft was afterwards comminuted, and roafted for three hours,

R 2　　　　　with

with the addition of powdered charcoal, yet
neither were any veftiges of arfenic difco-
vered, nor was the magnetic power deftroy-
ed; but the weight was now 105, and the
colour little changed. This powder, fufed
for an hour with lime and borax, yielded a
regulus of 72 lb.; this was red, angular,
femiductile, and altogether magnetic, the
fpecific gravity of it was 8,8750. The
fame globule, diffolved in aqua regia, was
indeed precipitated by martial vitriol, as if
loaded with gold; but the fediment was very
eafily foluble in nitrous acid, hence it ap-
pears not to be gold. But moft of the re-
guli which we obtained, fhewed no figns of
precipitation with martial vitriol; hence it
clearly appears, that even if gold be fome-
times prefent, yet it is not always the
cafe.

(H) 800 parts of the ore of nickel, which
is found in Saxony at Johan-Georgenftadt,
roafted for fourteen hours, and freed as
much as poffible from arfenic, by means of
powdered charcoal, loft 248 of their weight.
After reduction, and the firft mineralization
performed in the ufual way, it was remark-
able, that the latter fulphurated regulus,
which before calcination weighed 230, af-
terwards was equal to 242; and after ano-
ther fulphuration of the fame kind in the
laft calcination, had its weight increafed
from 70 to 78: the regulus laft obtained
was equal to 27, obedient to the magnet
poffeffing

oſſeſſing a ſpecific gravity of 7,3333, and
ielding with borax an hyacinthine glaſs :
t was with difficulty calcined, but at length
ell into a greeniſh powder, and with ni-
rous acid yielded a ſolution of the ſame
olour.

(1) The proceſs of mineralization and
alcination deſcribed in (H), was repeated
with 100 parts of the ore of Los, and that
without any increaſe of weight : the regulus
inally obtained was in abſolute gravity 1,
n ſpecific gravity about 8 ; it tinged borax
f an hyacinthine yellow, and nitrous acid
f a green colour.

§ VI. Nickel depurated by Hepar Sulphuris.

As it appears from experiment, that co-
balt is more eaſily diſſolved than nickel, by
hepar ſulphuris, and that theſe ſubſtances
may thus to a certain degree be ſeparated in
he fire ; a ſuſpicion aroſe, that unequal de-
grees of affinity might produce the ſame
effect with iron and nickel.

(A) 58 parts therefore of regulus of nickel,
which had before been ſulphurated (§ V. G),
fuſed with 1800 of ſaline hepar ſulphuris,
then diſſolved in warm water, filtered through
paper, and precipitated by an acid, yielded
a powder, which, roaſted in a diſh till the
ſulphur was conſumed, was found of an
aſh-colour, and weighed 35.

R 3   (B) The

(B) The refiduum, which could not be diffolved in warm water, being freed from fulphur by means of fire, was alfo of an afh-colour, and weighed 334.

(c) This refiduum, reduced by the black flux, yielded a friable regulus, which was indeed but little magnetic, yet, when fufed again with borax, exerted that property (which had before been weakened by the fulphur) in a higher degree.

(D) The fame experiment was tried with a calcareous hepar, according to the direction of Mr. Beaumé—viz. calx of nickel, gypfum, colophony, and white flux, were taken in equal proportions; thefe, mixed and fufed, yielded a powdery, fquamous, reguline mafs, which, when fufed with borax, produced a regulus poffeffing the properties of nickel (but not entirely deftitute of cobalt), which obeyed the magnet, and even after two folutions in nitrous acid, and various reductions by fufion with borax, did not part with its iron; it alfo retained the fulphur obftinately.

(E) Regulus of nickel was diffolved, in the via ficca, by a faline hepar fulphuris, and upon the addition of a quantity of nitre, fufficient only to deftroy a fmall part of the hepar, the regulus which had been fufpended by it was feparated and fell to the bottom. This regulus of nickel, up-on examination, appeared more pure, and generally, at leaft for the moft part, deprived

of

of cobalt, but ſtill containing iron. In like manner nickel is always very diſtinctly precipitated by regulus of cobalt, as this latter is attracted more powerfully by the hepar ſulphuris.

Nickel diſſolved by ſaline hepar ſulphuris in fuſion, may be precipitated by the addition of iron, copper, tin, or lead, and even by cobalt: the regulus obtained is ſcarcely ever attracted by the magnet; but whoever concludes from thence that no iron is preſent, will be deceived; for this metal (the regulus of nickel), when properly freed from the heterogeneous matters which impede its action, acknowledges the magnet's power very plainly.

§ vii. *Nickel depurated by Nitre.*

Finally, Nitre, which attracts phlogiſton more powerfully than any other ſubſtance hitherto known, was employed; it was hoped that this would more eaſily ſcorify the heterogeneous matters, becauſe nickel ſeems both to loſe its phlogiſton more ſlowly, and to recover it more quickly, than thoſe matters.

(A) One part of Cronſtedt's regulus was added to twelve of nitre, ignited in a crucible, and kept in an equable degree of heat for the ſpace of an hour; at firſt ſome weak flaſhes appeared, probably from the reſiduum of the ſulphur; afterwards a large

R 4   quantity

quantity of arfenic was thrown out ; finally, the fides were covered with a blue cruft, occafioned by the cobalt, and a green matter remained at the bottom. This fufed again for an hour, with twelve parts of nitre, tinged the internal fides of the veffel of a green colour ; and finally a brownifh green mafs, much lefs in quantity than in the former operation, was found collected at the bottom.

The green matter, treated in the fame way a third time, for two hours, left a grey fcoria at the bottom, which, with black flux, yielded no regulus.

Another portion of the fame regulus, fufed with nitre in the fame way, was dif-folved and became green ; yet, being freed from the alkaline falt by means of water, neither did this yield any regulus with black flux, but fcoriæ of an hyacinthine colour, mixed with blue ; which tinged nitrous acid of a green colour, concreted into a jelly, and upon evaporation left behind a greenifh calx.

(b) Another portion of Cronftedt's re-gulus was kept fome hours in the crucible, with fixteen parts of nitre ; by this means, at firft all the arfenic was feparated, then the phlogifticated nitrous acid flew off, and finally blueifh green flowers penetrated the fides of the veffel. The mafs being freed from alkali by water, and dried, was of a
                                        dilute

dilute green, and tinged borax of a greenish brown.

This was again treated in the same way with 12 parts of nitre ; and after edulcoration yielded a powder still green, which, reduced with $\frac{1}{2}$ black flux, $\frac{1}{4}$ lime, and $\frac{1}{8}$ borax, in half an hour yielded a yellowish white regulus, both magnetic and malleable, and possessing all the properties of nickel ; its specific gravity was 9,000. The inflammable ingredient was used in small quantity, that if possible the iron might enter the scoriæ.

(c) One part of the ore of los was strongly ignited in a crucible, for the space of an hour, with eight parts of nitre, and a detonation more distinct than with the regulus took place at first. The metallic calx, which was separated from the saline matter by water, was of a brown ferruginous colour, similar to that which is wont to remain after calcination with charcoal-dust. This by reduction yielded an ashen-white regulus, tenacious and magnetic, of the specific gravity 8,5573 : the scoriæ were black. The regulus reduced to powder, and fused with 12 parts of nitre, lost much cobalt ; and yielded a green calx, which, on reduction with double its weight of black flux, and $\frac{1}{2}$ quick-lime and borax, left nothing but distinct globules of nickel, tenacious and magnetic.

(D) One

(D) One part of Cronftedt's regulus was fufed for three hours with 8 parts of nitre, in a crucible, to the cover of which an open glafs tube was fo adapted that the afcending vapour might be collected there: the operation being finifhed, white arfenic was found in the upper part of the tube; but in the lower a powder of a brown afh-colour, a little green, which tinged borax of an hyacinthine colour, and yielded a regulus fo loaded with arfenic as not to be magnetic. The fides of the crucible were blue; but the faline green mafs at the bottom on elixation depofited a green calx, which was kept ignited with 12 parts of nitre for the fpace of an hour, and became partly blue, partly green: but afterwards, when only $\frac{1}{4}$ of the green refiduum was treated in the fame way, the whole appeared blue: yet the green refiduum was diffolved in nitrous acid, and rendered borax of an hyacinthine colour; fo that it confifted of nickel furrounded by a blue cruft.

(E) As the experiments above related fhew, by means of nitre, the fmalleft traces of cobalt, which otherwife would be completely latent, I examined the various niccoline products in difhes, with the addition of nitre, under the dome of an affay furnace: namely, 1ft. The regulus (§ IV. 1.) which was a little blue. 2d. The regulus previoufly diffolved in volatile alkali (§ X. A.) which manifefted a confiderable

quantity

quantity of cobalt that had lain hid before. 3d. The regulus previously sulphurated, which assumed a bluish pellicle. 4th. The globules (c), which sent forth a copious quantity of blue flowers. 5th. The sublimate of the preceding article (D), which shewed exceeding weak signs of a blue : and finally, 6th. The hyacinthine scoriæ of nickel, which were of a beautiful blue, yet contained so little cobalt that all the colour could be discharged from the glass of borax tinged by it, by means of the blow-pipe; which yet, on the addition of a small quantity of nitre, becomes blue : for the nature of metallic calxes is such, that they tinge glass the more deeply as they are more spoiled of phlogiston ; and, on the contrary, when they recover their principle of inflammability to a certain degree, all tinge vanishes. The former of these effects may be produced by nitre, the second by fusion on charcoal, provided the calx be so small in quantity, and so greedy of phlogiston as to be saturated by it from the coal ; otherwise these hyacinthine scoriæ tinge acids of a green colour, and are precipitated like nickel by phlogisticated alkali.

§ VIII. *Nickel depurated by Sal Ammoniac.*

As iron is easily sublimed by means of sal ammoniac, it was tried, in the following manner,

manner, whether nickel could by this me-thod be freed from iron.

(A) A calx of nickel, fo much freed from cobalt as not to tinge borax with the flight-eft blue, was mixed with double its weight of fal ammoniac, put into a cucurbit covered with an head, and expofed to a fire gra-dually increafed until the glafs grew red: the bottom was ftained with a very deep hyacinthine colour, and exhaled flowers, which adhered to the fides; thefe were partly afh - coloured, and partly white; which laft did not rife fo high as the former.

The refiduum exhibited two ftrata, the upper of which was yellow, fquamous, and fhining, like aurum mofaicum: it yielded with borax an hyacinthine glafs, but no regu-lus; after a few days it liquefied in the air, acquiring the confiftence of butter, and a green colour. This refiduum, with warm water, fhewed the fame properties and co-lour as calx of nickel; and the folution, which was green, became blue with volatile alkali, but with tincture of galls fhewed no veftiges of iron; a circumftance which alfo took place in the flowers.

The inferior ftratum contained a calx of nickel not yet converted into vegetations, and fomewhat contaminated with marine acid: the colour was blackifh, and, at the bottom, of a ferruginous brown. With bo-rax it yielded an hyacinthine glafs, and a

friable

friable regulus of a reddiſh white, and ſcarcely magnetic.

(B) A part of the inferior ſtratum (A), ſublimed with double its quantity of ſal ammoniac, with the ſame degree of heat as before (which precife degree was employed in the following) yielded an hemifphere of an hyacinthine colour, and flowers of a very fine white; but the refiduum was of a ferruginous brown, greeniſh on the upper part towards the fides of the veffel.

(C) To a portion of the inferior ſtratum reduced, was added 20 parts of ſal ammoniac, which were ſublimed in a retort; a blackiſh powder remained, which, as well as the bottom of the veffel, by calcination put on a green, and by ſcorification an hyacinthine colour.

(D) To the powder remaining (C) was added a double quantity of ſal ammoniac, which was again ſublimed extremely white, and the greeniſh maſs which remained was of a ferruginous brown at the lower part.

(E) Sublimation was performed with the refiduum of (D) and a double quantity of ſal ammoniac, and yielded as before exceeding white ammoniacal flowers; and the refiduum, which was very green, was altogether like a calx of nickel diffolved with the ſame colour in nitrous acid, and by reduction yielded a regulus of nickel, white, brittle, and very little magnetic.

In

In each fublimation the volatile alkali rofe firft, then fal ammoniac, and finally a portion of marine acid came over into the receiver.

§ IX. *Nickel depurated in the humid Way by nitrous Acid.*

After fo many experiments made by the via ficca, many others were tried in the way of folution, beginning with the cryftallized falt, (which, being compofed of nitrous acid and nickel, fhall be called nitrated nickel) by which, if poffible, the iron being de-phlogifticated, would feparate from its men-ftruum.

(A) Nitrated nickel, fprinkled during calcination with charcoal-duft, fent forth a large quantity of arfenic, and after reduction yielded a regulus, grey, femi-ductile, and magnetic.

(B) This being again diffolved in nitrous acid, precipitated by fixed alkali, and reduced, yielded a brittle regulus.

(c) The fame being a third time diffolved, yielded a regulus femi-ductile and magnetic.

(D) This operation was repeated a fourth time.

(E) The regulus, when diffolved a fifth time, was fo much diminifhed, that the white calx obtained by precipitation could not be any farther examined.

In

In all thefe folutions a blackifh refiduum prefented itfelf, which, when fuffered to remain in the acid, grew white by degrees ; but when edulcorated, and laid on a burning coal, exhaled a fulphureous fmoke, and left a black powder foluble in nitrous acid.

§ x. *Nickel depurated by Means of volatile Alkali.*

In order to difcover the effect of cauftic volatile alkali, in depurating nickel, a portion of the regulus of Cronftedt, diffolved in nitrous acid, precipitated by fixed alkali, edulcorated, and dried, was treated in the following manner :

(A) 487 parts of this calx, immerfed in a fuperabundance of volatile alkali, after twenty-four hours yielded a refiduum = 50, of a blackifh green, and a folution of a blue colour, which, when filtered and infpiffated to drynefs, yielded a powder of a light blue colour = 282 : this, reduced with black flux, produced a regulus, white, femi-ductile, and highly magnetic, = 35, and whofe fpecific gravity was 7,0000 : the fcoria which remained was a light red, but, mixed with borax, put on an hyacinthine colour, which yielded a regulus = 30. This regulus, united with the former by means of fire, was very refractory, fo that even with the addition of borax it could not be fufed by the blow-pipe : during calcination,

cination, with an abundant addition of char-
coal-duft, it did not fend forth a fmell either
arfenical or fulphureous : in a following
reduction it yielded an hyacinthine fcoria,
and the remaining flocculi, diffolved in ni-
trous acid, formed a very green folution,
which, upon addition of volatile alkali, let
fall a powder of the fame colour.

(B) From 50 parts of the blackifh green
refiduum was obtained a regulus of a clear
white colour, brittle, fquamous, but little
magnetic, = 13, and of a fpecific gra-
vity = 9,3333. A fcoria of an obfcurely
blue colour, the upper part of it hyacin-
thine, was found at the bottom of the vef-
fel. The regulus was eafily fufed, and tinged
borax firft of a blue, then of an hyacinthine
colour, upon which it grew more ftrongly
magnetic : by the affiftance of heat it dif-
folved in nitrous acid, and was of a beauti-
ful blue. During this folution a black pow-
der appeared, which firft floated like floc-
culi, but became white, and fell to the bot-
tom ; and after edulcoration, being expofed
to the fire, was for the moft part diffipated
with a fulphureous fmell ; but there ftill re-
mained at the bottom a little mafs of a
brown colour, foluble in volatile alkali :
this folution was precipitated by phlogifti-
cated alkali, and a powder thrown down of
the colour of calx of nickel ; this foon grew
blue with volatile alkali.

Hence,

Hence, therefore, it appears, that nickel is eafily and totally diffolved in the volatile alkali, unlefs the efficacy of the menftruum be obftructed by the prefence of fulphur.

§ XI. *Nickel can fcarcely be obtained in a State of perfect Purity.*

Upon confidering all the experiments above related, it eafily appears, that it is fcarcely poffible to obtain a perfect and compleat purification of nickel from all heterogeneous mixture, by any means, at leaft, hitherto known. The fulphur is with difficulty expelled by calcinations and folutions (§ III. L; IX. and X.); arfenic adheres ftill more ftrongly (§ III. and IV.); but by means of charcoal-duft and nitre is entirely expelled (§ III. N; VII. B); cobalt adheres the moft pertinacioufly of all, for by the addition of nitre its prefence has been detected even in products where it could not by any other method. No doubt its quantity had been fo much diminifhed by the nitre, that in folution it was totally imperceptible (§ VII. D), would fcarcely tinge borax, and the tinge which is communicated is difcharged with the blow-pipe, by the phlogifton of the charcoal; all which circumftances (as the colour of cobalt is very rich) demonftrate its being prefent in exceedingly fmall quantity (§ VII. E): but I am the rather inclined to think, that even

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this fmall portion may be feparated ; be-
caufe it is certain that the laft productions
of the blue colour are not to be afcribed to
cobalt but to manganefe, as we fhall demon-
ftrate more clearly hereafter (§ XII.) ; yet in
practice the feparation is extremely trouble-
fome ; for thefe reliquiæ, extracted by the
nitre, envelop the nickel itfelf (which in
this operation becomes very fpongy) and
adhere fo clofely to it, that mechanically
they cannot poffibly be feparated, and fcarce-
ly by menftrua, as both the fubftances are
thereby diffolved : by fire too they enter the
fcoriæ ; at leaft in thefe two methods fo little
difference is difcernible, that unlefs a large
quantity together be fubjected to the ope-
ration, all the nickel vanifhes together with
the cobalt.

In the prefent cafe then the iron alone re-
mains, and the quantity of this cannot be
diminifhed beyond certain limits ; the mag-
net readily difcovers its prefence, and not
only the reguli, tried in different ways, rea-
dily adhere to it, but fome of them actually
acquire a magnetic power (§ V. G), a circum-
ftance highly worthy of obfervation : but the
tenacity and difficulty of fufion, which in-
creafe the more as the operations are longer
continued upon the nickel, plainly fhew
that no hope remains of feparating the iron ;
fo that neither the fcorifications, nor the fal
ammoniac (§ VIII.), nor the nitre, nor the
nitrous acid (§ IX.), nor, finally, the volatile
alkali

alkali (§ x.), have effected this purpose; although Juncker says, that nitre attacks iron so powerfully that from a pound of steel filings, detonated with an equal quantity of nitre, then fused and elixated, no more than half an ounce of crocus is obtained.

Besides these heterogeneous matters, bismuth is also sometimes present; but this is very easily separated; for if the solutions made in acids be sufficiently diluted with water, the menstruum is so much weakened, and the calx of bismuth falls to the bottom like a white powder.

§ XII. *Whether Nickel be a distinct Metal.*

It may now be properly enquired, whether nickel be a distinct metal, or whether it be a mixture made by the hands of nature, from others intimately united?—We have already observed that arsenic, copper, cobalt, and iron, have been by various authors considered as its proximate principles.

With respect to arsenic, we may very safely exclude it from the number, as the experiments above described shew that it may be entirely expelled.

It cannot be doubted but that copper is present in some ores of nickel, and therefore may easily be mixed with the regulus; but the greater number are entirely without it. It is true that nickel is totally soluble in volatile alkali, and that this solution

lution

lution is of a blue colour (§ x. B); but if this argument held, there would be nothing found here but copper; and if this were the cafe very different phænomena would appear from thofe which the nickel produces. That both thefe fubftances form with volatile alkali folutions of the fame colour, no more proves the identity of thefe fubftances, than does the yellownefs of the folution both of gold and iron in aqua regia, prove the identity of thofe metals. Nickel and copper agree alfo in this property, that they are both precipitated from acids, and from volatile alkali, by iron; but in the manner of this precipitation a confiderable difference appears. Let a piece of polifhed iron be plunged into a folution of nickel, and a yellow pellicle of nickel will by degrees adhere to it; which difappears upon touching, and foon grows black, unlefs the acid be well faturated or fufficiently diluted with water. A fimilar precipitation is obferved if zinc be ufed inftead of iron; but in folution of copper fo much diluted that the precipitation on iron may be nearly fimilar to that of nickel, zinc is immediately covered with a cruft of the colour of mountain brafs.

The experiments above defcribed fufficiently fhew that cobalt does not belong to the effence of nickel (§ x. XIII. K); yet to thefe we fhall add the following:—Nickel, diffolved in hepar fulphuris, is precipitated

by

by cobalt ; with what justice then can we
affirm them to be one and the same ? In the
same way, nickel tinging borax or micro-
cosmic salt, in the via sicca is thrown down
by the addition of a proper quantity of cop-
per ; but this is not the case with cobalt.
These circumstances are so remarkable as of
themselves to banish all doubt. But with
the acids a remarkable difference constantly
occurs—1st, Cobalt tinges all these menstrua
of a red colour, and yields crystals either of
a yellow or bluish red ; but nickel produces
solutions and concretions of a fine green ;
it sometimes happens indeed that the red so-
lutions yield greenish crystals ; but this is
to be attributed to nickel mixed in small
proportion with the cobalt. 2d, Cobalt,
united with marine acid, affords a sympa-
thetic ink ; but depurated nickel does not.
3d, Cobalt, dissolved in volatile alkali, is red ;
but nickel, dissolved in the same alkali, is
blue. 4th, Cobalt does not, like nickel, se-
parate, upon the addition of arsenical acid,
a powder difficultly soluble. Many other
points of difference there are, which may be
passed over in silence.

Iron therefore only remains ; and indeed
there are many and weighty reasons which
induce us to think that nickel, cobalt, and
manganese, are perhaps to be considered in
no other light than modifications of iron.

And first—in general we observe, that un-
equal portions of phlogiston, united to the

fame

fame iron, change its qualities in a remark-
able manner : for inftance, how very much
do the different kinds of iron and fteel dif-
fer ? It is then to be obferved, that nickel,
cobalt, and manganefe, whatever operations
they may be fubjected to, are fo far from
being deprived of iron, that on the contrary
they thereby become more ductile, mag-
netic, and refractory. Again, the various co-
lours which nickel, cobalt, and manganefe
exhibit, both by folution and by fire, are
alfo exhibited by iron. Cobalt and manga-
nefe occafion a red colour in acids, and the
latter in glafs ; nickel and manganefe occa-
fion an hyacinthine colour when fufed with
borax ; a green is produced in acids by
nickel, as alfo by its calx, and by manganefe
(M), when long and ftrongly calcined; and it
often leaves behind a fcoria of the fame co-
lour, if the reduction be performed with a
faline flux. Finally, cobalt occafions a blue
or rather a violet colour in glafs ; and the
fame is true of manganefe diffolved in fixed,
and nickel in volatile alkali.

Iron too exhibits all thefe varieties ; for
the acids take up this metal of a green co-
lour, fo long as it contains a certain quan-
tity of phlogifton ; but, in proportion to the
diminution of this principle, a yellow, a red,
or a brownifh red colour is produced. It
tinges glafs, in the fame manner, green, yel-
low, black, or red. If expofed to the fire for
many hours together, with nitre, the bot-

tom

tom and sides of the crucible, it is true, tran-
sude saline flowers, either blue, greenish
blue, or greenish purple ; but an efflores-
cence of the same kind is occasioned by
nitre alone ; for this salt, by a long-con-
tinued fire, penetrates the vessels, and im-
mediately upon contact of ignited phlo-
giston is decomposed, and the alkaline efflo-
rescences are made blue by the manganese,
which is always present in the circumjacent
ashes ; these verge more to a green in pro-
portion as the crocus martis is more co-
pious ; besides, iron itself is often found
mixed with manganese.

From hence, therefore, it appears, that
the blue flowers, which were expelled from
nickel by means of nitre, are the produce
of manganese, as these impart to glass no-
thing of the cobalt colour ; besides, in the
mineral kingdom we find the nephritic, smeg-
matic, serpentine stones, and jaspers, clays
called from their colour *terres verdes*, and
other green stones, *lapis lazuli*, native Prus-
sian blues and other blue stones, together
with many diversities of yellow and red, all
deriving their colour from iron.

Whoever rightly considers these circum-
stances will think it not an improbable con-
jecture, that these semi-metals are derived
from iron, of which they cannot be entirely
deprived ; and from hence will take occa-
sion to examine this opinion by new experi-
ments and observations, which may either

serve

serve to establish or overturn it. In the mean time we should be carefully on our guard against such glimmering lights, which are generally fallacious. So long as no one is able to produce any of these metallic bodies from pure iron, and to explain, in a clear and intelligible way, the process by which manganese, cobalt, or nickel, may at pleasure be generated, such vague suspicions must give way to phænomena and properties which are constant, and the substances themselves continue to be considered of an origin altogether distinct and peculiar to themselves. It is sufficient for our purposes, that these metals possess distinct properties, and always preserve their own peculiar nature, until we shall be better instructed by faithful analysis and synthesis. There is no doubt that many metals, which have been a long time known and acknowledged to be distinct substances, would scarcely have endured more severe trials than nickel does. By the same rule, therefore, such metals may be alledged to be compounded. If the genesis of natural productions was to be established by fancied metamorphosis, the whole truth and certainty of natural philosophy must soon be overturned. So long as plausible conjectures are substituted for opinions formed on the sure base of experiment, we shall always embrace the shadow for the substance.

§ XIII. *Syn-*

§ XIII.   *Synthetical Experiments.*

Although the fynthetical experiments which I undertook with intent to difcover the origin of nickel, were in that view in-effectual, yet I think it proper to relate the principal of them, that the way may be more eafy to others. The fpecific gravity of the copper, iron, cobalt, and white arfenic, employed, were 9,3243, 8,3678, 8,1500, and 4,0000, refpectively.

(A) Equal parts of copper and iron, united by fufion with black flux, yielded a red mafs, whofe fpecific gravity was 8,5441, which tinged nitrous acid firft blue, then green, afterwards yellow, and at length an opake brown.

(B) Two parts copper, and one of iron, united, had a fpecific gravity equal to 8,4634. The mixture yielded firft a blue, then a green folution.

(C) Equal parts of copper, iron, and co-balt, yielded a regulus of the fpecific gravity 8,0300, which imparts to the menftruum a brown colour.

(D) One part of copper, one of iron, and two of arfenic, formed a brittle mixture of a fpecific gravity equal to 8,0468, which formed a blue folution.

(E) One part of copper, one of iron, two of cobalt, and two of white arfenic, yielded a brittle compofition of a fpecific gravity

equal

equal to 8,4186, which gave a brownish red solution, and in part precipitated spontaneously.

(F) One part of copper, one of iron, four of cobalt, and two of white arsenic, united by fusion, formed a mass of specific gravity equal to 8,5714 : the regulus, dissolved in nitrous acid, was as in (E), but more red.

(G) One part of copper, one of iron, four of cobalt, and two of white arsenic, acquired a specific gravity equal to 8,2941 ; they were dissolved with a red colour, and deposited a sediment.

(H) One part of iron, and four of white arsenic, fused, were dissolved with a yellow colour ; and, on the addition of phlogisticated alkali, immediately yielded a Prussian blue.

All these mixtures, exposed to the fire, left a calx, not green, like that of nickel, but brown, black, or ferruginous.

(I) One part of copper, eight of iron, sixteen of white arsenic, and four of sulphur, united by fire, on the addition of black flux, yielded a mass, which, though frequently calcined and reduced, yielded nothing but a ferruginous or brown calx : with nitrous acid it acquired a greenness, but on the addition of phlogisticated alkali, deposited a Prussian blue.

(K) Many experiments were also tried in the way of solution ; one of which it will be sufficient to mention.

One

One part of iron was diffolved in fix of nitrous acid, and alfo feparated by one part of copper, and one of the calcined ore of cobalt, in the fame quantity of the fame acid; then the whole of the folution of iron was mixed with five parts of the folution of copper, whence a green and faturated nickel colour was formed, which, however, upon the addition of three parts of the folution of cobalt, was evidently obfcured: the alkaline lixivium was dropped into this, by which at firft a ferruginous brown fediment fell, the folution ftill remaining green; but afterwards all the blue was precipitated, by which at firft all colour was deftroyed; but afterwards a red appeared, occafioned by the cobalt diffolved in the alkaline falt. The fediment, when reduced, yielded a regulus fimilar to copper, and ductile, which tinged both glafs and nitrous acid of a blue colour.

If a faturated folution of nickel be mixed with half its quantity of folution of cobalt, the green colour is much obfcured; but four parts of the former, upon the addition of three of the latter, put off all appearances of nickel.

§ XIV. *Properties of depurated Nickel.*

I have not been able to determine accurately what are the properties of nickel when perfectly pure, as the perpetual prefence of

iron

iron in fome refpect obfcures its pro-
perties.

(A) The fpecific gravity cannot be afcer-
tained, efpecially as the quantity of iron is
unknown. Let us fuppofe that the pureft
nickel we can obtain, contains of iron a
weight $= p$, and of real nickel $= q$; as alfo
that the fpecific gravity of the former ingre-
dient is f, of the latter n, and of the mix-
ture a; then, from the known laws of hy-
droftatics $\frac{a\,q\,f}{p\,f + q\,f - a\,p}$. Now it appears by
experiment, that the weight of iron is more
increafed by calcination than that of any
other metal, even to $0,36$: fince then the
calx of purified nickel increafes $\frac{1}{6}$ (§ IV. G),
if one half be afcribed to the nickel, as
much muft necefarily belong to the iron:
befides, let $\frac{1}{2}$ the increment be fubtracted, as
owing to the charcoal-duft, neverthelefs the
refiduum fhews that more than $\frac{1}{4}$ confifts
of iron. Let therefore $p = 1$, $f = 8,000$,
$a = 9,000$ (§ VII. B), q will be $= 2$, and
$n = 9,600$. The data of this calculation
were fo taken, that the value of n fhould
come out lefs than the truth; for the in-
crement of the nickel is put equal to that
of the iron, which is hardly probable; then
the quantity of iron is eftimated only at $\frac{1}{4}$,
although it is certainly greater; and finally,
$\frac{1}{4}$ of the increment is afcribed to the char-
coal-duft, although other experiments fhew
that it adds little or nothing to the weight;
hence therefore we conclude, that the true
fpecific

specific gravity of nickel is not less than 9,000 at least. The calculation indeed supposes that the bulk remains unchanged in the mixture, which is a thing that rarely happens; but the error thence arising never exceeds 0,7, so far as is yet known, and perhaps, in the present case, is rather to be added than subtracted.

If a small portion of gold entered the composition, the greatness of the weight might thence be explained; but although this metal is almost always absent, as we have before observed (§ v. G), yet thirty-six parts of it, forty-eight of iron, and one of copper, were formed by fusion into a globule, the specific gravity of which was 8,8571, but was little soluble in nitrous acid; yet, after lying two hours in the menstruum, the gold was to be seen plainly, and with volatile alkali, the menstruum yielded nothing but a ferruginous brown precipitate, which in the fire put on the appearance of roasted iron; in all which particulars it differs from nickel.

(B) The solutions of nickel in all the acids are of a green colour. The vitriolic acid takes up the calx, and forms a green decaedral salt, of an aluminous compressed figure, the two opposite apices truncated; this acid scarcely attacked the regulus but by evaporation to dryness. The nitrous acid, by the assistance of heat, dissolves both the calx and the regulus, and forms blueish-

green

green cryftals, fpathofe and deliquefcent.
The marine acid diffolves both the regulus
and the calx, but flowly, and not without
the affiftance of heat. Both nitrated and
falited nickel, when frefh, deliquefce; but
by long continuance in a free and warm air,
gradually lofe their acid, fo that at length a
green calx of nickel, mixed with iron and
arfenic, remains behind. Acid of arfenic,
with the calx of nickel, concretes into a
green faline mafs; but with the regulus it
feparates a faline powder difficult of folu-
tion. The fluor acid forms with calx of
nickel (which it does not eafily diffolve)
cryftals of a dilute green. The acid of
borax fcarce diffolves nickel directly, but
takes it up by means of a double elective
attraction. Vinegar forms with the calx
fpathofe cryftals of an intenfely green co-
lour: it is fcarcely diffolved by acid of tar-
tar, at leaft this menftruum is not tinged
by it. Acid of fugar changes both the
regulus and the calx to a white powder,
not eafily foluble in water. The acid of
phofphorus has but little attraction for the
calx of nickel, with which it does not form
cryftals, nay the folution is fcarcely green.
The acid of ants, by decoction or long di-
geftion, attacks the newly-precipitated calx;
for the folution is green, and upon evapo-
ration yields cryftals of a deep green colour;
thefe are hemifpherical, formed of filaments
diverging from a center, and pellucid; they
reject

reject spirit of wine, and are scarcely soluble in water, unless it be sharpened by an acid. Lemon-juice does not seem to act at all upon nickel.

All the acids are tinged of a very deep colour, and this property of nickel is extremely powerful; for the first regulus (D), as well as that which is highly depurated, occasions these tinges. This great richness of colour agrees well with the idea of a large quantity of matter in a small bulk.

Volatile alkali dissolves nickel, and the solution is blue; the fixed alkali dissolves very sparingly, and forms a yellow solution.

(c) In proportion as nickel is more pure, it is the more difficult of fusion, so that when at its great degree of purity it requires for fusion nearly as great a degree of heat as forged iron: it is easily fused with other metals, but its scarcity has prevented us from examining the phenomena arising from hence. In general, however, we may remark, that the impure regulus cannot unite with silver: this must be attributed to the cobalt which it contains; for when well freed from that metal, it easily unites in equal proportions with the silver, and that without any remarkable diminution either of whiteness or ductility. This mixture, fused with borax, tinges it of an hyacinthine colour. Copper unites more flowly
with

with depurated nickel, yielding a red and ductile metallic mafs, which tinges borax of a reddifh hyacinthine colour. With an equal or even a greater bulk of tin, nothing is produced but a brittle mafs; in which refpect alfo nickel differs from cobalt. It could not be amalgamated with mercury by trituration. Depurated nickel melts with tin, and forms a brittle compound.

It may feem doubtful, whether nickel is to be enumerated among the ductile or the brittle metals. Iron, when fufed, is almoft always brittle, fo that its ductility, when united with nickel, is very remarkable.

(D) Depurated nickel is with great difficulty calcined in the ordinary way in the affay-furnace, and affumes only a brown colour; but by means of nitre it is more compleatly dephlogifticated, and becomes green. The metallic calx, vitrified with borax, produces an hyacinthine tinge, which yet, if occafioned by a regulus not well depurated, vanifhes on continuing the fire, the glafs remaining being altogether colourlefs, and upon the addition of nitre only a flight blue tinge is produced. A calx of well-depurated regulus of nickel forms a permanent colour. The calx of nickel communicates alfo to microcofmic falt an hyacinthine colour, which, by long-continued fufion on charcoal, may indeed be weakened, but hardly entirely difcharged : this colour, on
the

the addition of nitre, changes to a violet, and on increasing the quantity of microcosmic salt, becomes again hyacinthine. If the calx of nickel be added to saturation, the fused glass appears of a blood colour, but upon cooling grows more and more yellow.

DISSERTATION XXI.

O F

A R S E N I C.

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§ 1. *Historical Introduction.*

ARSENIC is found in the bowels of
the earth, either in a metallic form
or calcined, or finally, intimately, and in
the way of solution, united with sulphur;
this diversity could not escape the first dis-
coverers, and hence their opinions concern-
ing its true nature were strangely contra-
dictory for a long time.

We are entirely ignorant at what time it
began to be distinguished from other mine-
rals, and when it received the name which
it still continues to bear. It is extremely
probable that this substance was first disco-
vered by those who wrought in the roasting
and fusing of ores, betraying itself by its
<div align="right">white</div>

white fmoak, its garlic fmell, and its per-
nicious effects in depraving metals and de-
ftroying animal life. Ariftotle mentions the
Σανδαραχη; and his difciple Theophraftus
Erefius fpeaks of Αρρενικος, which was called
Αρσενικος by Diofcorides and others, who
lived about the beginning of the Chriftian
æra. But thefe denominations compre-
hended only thofe minerals which by Pliny,
and other Latin authors, are called fandarach
and orpiment. Avicenna, a chemift of the
eleventh century, who, fo far as we know,
was the firft who diftributed minerals into
ftones, metals, falts, and fulphurs, not only
fpeaks of white arfenic, but, what is re-
markable, of its fublimate. Theophraftus
is the laft who mentions the regulus, al-
though he had before referred fandarach and
orpiment to the metallic ftones. It is un-
known who firft reduced white arfenic to
a metallic form. Paracelfus, in his Ma-
nual, afferts that arfenic, fublimed with
lime of egg-fhells, becomes like filver;
and in the year 1675, Lemeri defcribed a
method of fubliming arfenic with fixed
alkali and foap; but in the year 1649, J.
Schroder mentions the regulus eliquated
from arfenic or orpiment by means of white
flux, charcoal-duft, and iron: he quotes
Cloffæus, but does not give the title of the
work. In the Pharmacopœia 1644, this
procefs is not to be found.

Avicenna,

Avicenna, and many after him, even to our times, place arfenic among the fulphurs: Albertus Magnus and others, among the faline bodies: Beecher confiders it as a foap, or a faline fulphureous body. Indeed, as white arfenic is foluble in water, it is plain that it contains fomething faline, although no appearance of fuch a thing can be difcovered either in the regulus alone or in its mineralized ftate. That this faline fubftance is of an acid nature, plainly appears from its ready union with alkalis, efpecially as the celebrated Macquer's experiments fhew, that neutral cryftallizable falts may be generated from thence; but until our countryman Mr. Scheele's time, no one had been able to extract this acid in its pure ftate, and the ingenious inventor has lately defcribed the method he purfued.

As to the fulphureous nature of arfenic, which fome perfons ftrenuoufly infift upon, it muft be confeffed that the regulus itfelf, nay even orpiment and realgar, are inflammable; a circumftance which however does not take place with refpect to white arfenic. If therefore the fulphureous quality is to be determined from a fingle property (in the fame way as the faline) it appears that it is only competent to arfenic in a certain ftate. But befides arfenic, zinc and feveral other bodies, which are eafily inflammable, are not however from thence to be denominated fulphureous,

phureous, unlefs we will confine that appel-
lation to the quantity and connexion of
phlogifton adapted to inflammation.

It is commonly faid that arfenic minera-
lizes metals, and therefore it is confidered
as a fulphur by fome, who yet extend the
idea of mineralization fo far, as under it to
comprehend all mixtures, whereof a metal
forms a part : but if we examine this figni-
fication a little more accurately, we fhall
eafily fee that it is extended too far ; for if
this be admitted, we muft at the fame time
allow that no native metal is to be found ;
thus the gold, which is called native, is
fcarce ever perfectly pure, but is mixed
more or lefs with filver or copper. In the
fame way filver is mixed with gold or cop-
per ; platina with iron ; copper with gold,
filver, or iron ; nickel with cobalt, &c. If
therefore arfenic, which, unlefs in its regu-
line ftate, never diffolves other metals (§ vi.
A), be confidered as a mineralizing fub-
ftance, what hinders us from faying that
gold is mineralized by filver and copper,
and in general every metal mineralized by
another ? Beyond doubt, the fame reafon
holds good in all. With much lefs appear-
ance of truth can we fay, that metals are
mineralized by earths, as thefe latter are
fcarce ever, except mechanically, mixed with
the ores.

It is much more conformable to reafon
and experience, to call thofe metals mine-

ralized

ralized which are diffolved, and actually concealed by a menftruum. Sulphur is the chief agent employed by nature for this purpofe; and although the acids of vitriol, of nitre, of phofphorus, and fometimes even the aerial acid, occafion the metals to put on an appearance foreign to their nature, yet the number of thefe is fo fmall, that, compared with the fulphurated minerals, they almoft vanifh.

But the idea of a mineralizing arfenic, perhaps, is to be fought for further. This mineral, fo troublefome to the mineralogift, occafioned the alchemifts to fufpect the exiftence of a certain arfenical principle indifpenfably neceffary to the perfection of every metal; a fufpicion occafioned by their ftrenuous endeavours, during the procefs of their great work, to difcover, by the moft fubtile ratiocinations, the true compofition of metals. Even fo late as the year 1773, the Royal Academy of Sciences at Berlin propofed the following problem : *Quid arfenico in mineris præfente efficiat natura ? Num idoneis evinci queat experimentis quod metalla re vera perficiat ? Et fi ita, quomodo & quoufque hoc fiat ?* The premium was adjudged to the anfwer of the celebrated Monnet, in which he, with great ingenuity and truth, confiders arfenic as a femi-metal differing from all others; which is fo far from conftituting an effential part of the texture of metals, that it unqueftionably is often totally
                                        abfent,

abfent, and when prefent, is always attended
by inconveniencies, either carrying it off in
its departure, or fpoiling the mafs. Cer-
tainly good copper is, though not without
difficulty, eliquated from the grey ore; and
filver, equally perfect, is obtained from the
vitreous as from the red ore. No one as
yet has been able to perfect any metal
by means of arfenic, and if it be acci-
dentally found mixed with others, it no
more contributes to their goodnefs, than
the lead in galena is ufeful to the filver,
or the filver to the lead. If recourfe be had
to an arfenical principle fo fubtile as to
evade the obfervation of our fenfes, let us
leave that fubject to be difcuffed by its au-
thors.

All thefe confiderations, however juft, do
not prevent us from afferting, that the acid
of arfenic, like other acids, is a mineralizing
fubftance, when at any time, in a difen-
gaged ftate, it meets with a metal in the
bowels of the earth, and in that form unites
with it.

Among the chemifts who have laboured
during this century to difcover the proper-
ties of arfenic, the celebrated Brandt muft
not be omitted, he being either the firft who
obferved many of them, or at leaft the moft
accurate in their defcription. Mr. Pott has
publifhed a learned treatife on orpiment;
J. G. Lehman, another on the fandarach of

T 4   the

the ancients ; and many other books there
are upon the fame fubject.

§ 11.   *Reguline Arfenic.*

Arfenic is found in a metallic form, in
Bohemia, Hungary, Saxony, Hercynia, and
elfewhere, but particularly at St. Marieaux
mines in Alfatia, where not long fince
many hundreds of it were extracted.   In
Germany it is called Schoerbencobolt, and
frequently Fliegenftein or Muckenpulver,
but for what reafon I know not, as it is not
foluble in water, and therefore, unlefs when
dephlogifticated, is not at all proper for the
purpofe alluded to by the name ; perhaps
by fpontaneous calcination it becomes fo
much dephlogifticated as to acquire a degree
of folubility.

As to its form, it is often found fhapelefs,
friable, and powdery, but fometimes com-
pact, divided into thick convex lamellæ,
with a needle-formed or micaceous fur-
face. It admits of a polifh, which yet is
foon loft in the air.

When frefh broken, it appears compofed
of fmall needle-like grains, with a leaden
colour, which yet foon grows yellow, and
by degrees blackifh : in hardnefs it feems
to exceed copper, in brittlenefs to equal
antimony.

A regulus

A regulus may also artificially be procured from white arsenic, either by subliming it with oil, black flux, or other phlogistic additaments; or fusing it with double its weight of soap and pot-ashes; or, finally, precipitating it by some other metal from orpiment or sandarach, fused with sulphur and fixed alkali. That which is obtained by the first of these methods has a crystalline form, more or less regular, octaedral, pyramidal, or even prismatic. Sometimes the artificial regulus is sold in thick cakes; its specific gravity is 8,310, and therefore a cubic inch weighs about 43,19 drachms avoirdupois.

The mineral commonly called mispickel, is justly reckoned a regulus, as, when totally deprived of sulphur, it consists of arsenic and iron united in a metallic form; and although the latter amounts to $\frac{1}{2}$, or sometimes even to $\frac{2}{3}$, yet the compound is not magnetic: this, when ignited, sends forth an arsenical smell, and is thus soon rendered magnetic, although the operation be performed on a tile, without any phlogiston: it easily flows in the fire, and in close vessels the greater part of the regulus of arsenic rises, leaving the iron at the bottom; a compound of this kind may also be artificially made.

Reguline arsenic is far more volatile, and loses its phlogiston more easily, than any other metal, and therefore it cannot be
fused,

fufed, as for that purpofe a greater degree of heat is neceffary than what is fufficient to calcine, volatilize, and inflame it. In open veffels it begins to fend forth a vifible fmoke, in a degree of heat $=$ 180° of the Swedifh thermometer: in order to inflame it, the regulus muft be dropped into a veffel of a proper degree of heat, for if the heat be gradually increafed, the metal is volatilized; the neceffary degree muft therefore be inftantaneoufly applied. The flame is of an obfcure whitifh blue, diffufing a white fmoke, and a garlic fmell; in clofe veffels it retains its metallic nature, and expofed to the fire is fublimed in a determinate figure.

§ III. *Habits of Reguline Arfenic mixed in the Via Sicca with other Subftances.*

(A) Arfenic in a reguline form, added to metals in fufion, melts with many of them, but thereby thofe which were malleable become brittle: fuch of them as flow with difficulty when alone, become more fufible by means of arfenic; but thofe which foon liquefy (at leaft tin) become more refractory: thofe which are yellow or reddifh are made whiter, according to the quantity of arfenic; and fuch as are white acquire a grey colour, tin excepted, which by this means acquires a permanent and fhining whitenefs, and

and by fusion is able to retain $\frac{1}{2}$ its own
weight; nor does it spoil the colour of platina
when united with it. Gold fused in a close
vessel takes up scarcely $\frac{1}{600}$, silver $\frac{1}{4}$, lead $\frac{1}{6}$,
copper $\frac{5}{6}$, and iron more than its own weight.
Iron, by means of a large quantity of this
metal, loses its magnetic power, but it is
difficult to determine exactly how much is
sufficient for this purpose (as some of the
iron always enters the scoria); but un-
boubtedly less than an equal quantity is
sufficient. Bismuth retains about $\frac{1}{15}$, zinc
$\frac{1}{5}$, regulus of antimony $\frac{1}{8}$, and manganese an
equal quantity. Nickel and cobalt receive
some arsenic, and that not a little; but the
quantity can hardly be determined, as these
metals are scarce ever got pure. Regulus
of arsenic, in a sufficient degree of heat,
and by triture of several hours, actually
takes up $\frac{1}{6}$ of its own weight of mercury,
and forms a grey amalgam.

By means of heat in an open vessel the
arsenic may be again expelled, but flying
off it generally carries with it some of the
metal with which it is united, gold and
silver not excepted, if the degree of heat be
great and suddenly applied; yet platina per-
fectly resists the volatilization, nay, being
very difficult of fusion, it even retains a
portion of the arsenic.

(B) Regulus of arsenic cannot be united
by fusion with alkaline salts until the phlo-
giston is sufficiently diminished; if, there-
fore,

fore, the regulus be added to nitre in fufion, after detonation they both eafily unite, and the compound comes out exactly fimilar to that made with white arfenic (§ VI. B).

(c) Regulus of arfenic, expofed to diftillation with the dry acid of arfenic (§ V.), fublimes before it can be acted upon by the acid, which muft be firft melted ; but the regulus, when put into the acid in fufion, foon takes fire, and fends forth a white fmoke ; for the acid, being deprived of its phlogifton in this inftance, feparates that principle from the regulus, and takes it to itfelf in fuch quantity as to regenerate white arfenic ; and on the other hand, the regulus, by means of the fire, is fo far fpoiled of its phlogifton, as to appear in the form of a calx.

(D) This regulus, in diftillation with corrofive fublimate, yields a fmoking butter, with a fmall quantity of mercurius dulcis and quickfilver. In this cafe the principles are changed ; by means of a double elective attraction, the regulus of arfenic yields its phlogifton to the bafe of the corrofive fublimate, which being thereby really calcined, is reduced into perfect mercury, while the marine acid takes up the calx of the arfenic.

(E) Sulphur eafily diffolves the regulus ; and by fufion and fublimation yields yellow or red compounds, according to the different proportion (§ X. B). Hepar fulphuris

phuris takes up the regulus; but this laſt adheres to it ſo looſely, that it is precipitated by every other metal which can unite with the hepar.

§ IV. *Habits of Regulus of Arſenic, united by the Via humida with other Subſtances.*

(A) Water alone has no effect in this caſe.

(B) Vitriolic acid does not attack the regulus, unleſs concentrated and aſſiſted by fire. The inflammable part of the regulus phlogiſticating the acid flies off, ſo that the remaining part aſſumes the nature of white arſenic, and with menſtrua exhibits the ſame properties as any other metallic calx.

The ſame is true of nitrous acid, except that it attracts the phlogiſton more vehemently.

Marine acid has ſcarcely any effect, un- leſs when boiling.

Acid of arſenic, which ſhall be ſpoken of hereafter (§ v.), by digeſtion changes the regulus into a white calx, and is itſelf al- together changed (by means of the phlogiſ- ton which it has taken) into a calx, pro- vided the phlogiſton be in due quantity.

The other acids I paſs over, as entirely refuſing to unite ſo long as the reguline form remains; for no metal, except when more or leſs deprived of phlogiſton, can be

diſſolved

diffolved in acids. This impediment is very
eafily removed by the nitrous acid, but very
difficultly by marine, as it abounds in phlo-
gifton itfelf. In this cafe, therefore, the
fame compounds are produced with the re-
gulus, as thofe with white arfenic, defcribed
in § VII. c.

It muft here be obferved, that folutions
of the native regulus always yield a Pruffian
blue with phlogifticated alkali; which evinces
the prefence of iron.

Befides, it is to be obferved, that the re-
gulus plainly precipitates certain metals dif-
folved in acids, fuch are gold and platina in
aqua regia, and alfo filver and mercury in
vitriolic or nitrous acid. The filver gene-
rally appears in beautiful polifhed fpiculæ,
like the Arbor Dianæ; but if the arfenic be
fuffered to ftand long in the nitrous folu-
tion, but little diluted, the filver fpiculæ are
again diffolved, the arfenic becoming in the
mean time dephlogifticated. Solutions of
bifmuth and antimony are but obfcurely
rendered turbid.

Arfenic and iron naturally united, as in the
mifpickel, may be feparated by digeftion with
marine acid or aqua regia; for the former
menftruum in this way only attacks the
iron; and the latter, although it can dif-
folve both, yet is not able to touch the
arfenic fo long as any iron remains. In or-
der, however, that all the arfenic may re-
main alone at the bottom, a very fubtile

3   pulverization

pulverization is neceſſary, together with a juſt quantity and ſtrength of the menſtruum, and heat muſt alſo be carefully avoided.

(c) The alkalis operate more ſlowly in the humid than the dry method, as, before a real union takes place, the phlogiſton muſt be diminiſhed. A ſaline hepar, by boiling, attacks the pulverized regulus ; for that which is precipitated by an acid, yields by ſublimation a true orpiment.

(D) The fatty oils, when boiling, diſſolve the regulus, and form a black maſs of the conſiſtence of a plaſter.

§ v. *Calcined Arſenic.*

The regulus, with a very gentle heat, loſes ſo much of its phlogiſton that it flies off in a white ſmoke ; yet all the metallic calxes retain much of their inflammable principle, although not ſufficient to give them a metallic appearance. The following experiments will plainly ſhew, that this is true alſo of arſenic :—Let calcined arſenic, moiſtened with nitrous acid, be expoſed to heat, and a copious red vapour will break forth, which, collected, exceeds the arſenic four or five times in bulk ; and, upon examination, is found to be no other than that which by the celebrated Prieſtley is called nitrous air ; however, this always abounds in phlogiſton, and ſcarcely contains any thing elſe, except a ſmall portion of ni-
trous

trous acid, dilated into an elaftic fluid by
the abundance of phlogifton. In this cafe
the inflammable principle can be derived
from no other fource than the arfenic ; and
we fhall foon have occafion to take notice
of other proofs.

The native calx of arfenic occurs but fel-
dom in Saxony and Bohemia ; but is found
copioufly in thofe places where the ores of
cobalt are roafted, and is collected in the
long and winding wooden tubes ufed in that
operation. This fmoke is found fo loaded
with phlogifton, that it appears grey ; but is
foon made white by fublimation, either with
or without pot-afhes. This calx is volatile,
but lefs fo than the femi-metal itfelf, for it
requires at leaft a degree of 195°. If in a clofe
veffel it be raifed by a fire a little higher,
it becomes pellucid like glafs. In the air
its furface foon contracts a white opacity ;
but that which is found cryftallized in the
bowels of the earth, is not fubject to this
change. The fpecific gravity of white arfe-
nic is 3,706, and that of the glafs about
5,000.

It flowly excites upon the tongue an acid
fubdulcid tafte.

White arfenic is in reality nothing elfe
but an acid different from all known acids,
and loaded with fuch a quantity of phlo-
gifton as is fufficient to coagulate it. 100
parts of white arfenic contain at leaft 20 of
phlogifton ; and whatever is capable of fe-
                                        parating

parating fo much, is capable of leaving the
acid pure. This acid (which has been exa-
mined particularly in another place) is of
itfelf fixed, but when made red hot decom-
pofes the matter of heat, gains phlogifton
from thence, and regenerates white arfenic,
which, loaded to faturation with phlogifton,
becomes reguline. The dry acid, expofed
to a moift air, deliquefces and falls totally
into a limpid liquor, containing fo much
water as is neceffary to the folution of the
acid in a moderate temperature, that is $\frac{2}{3}$ of
its own weight.

It is highly probable that all the metals
are only different acids coagulated by a
large quantity of phlogifton, although the
connection of thofe principles is fo clofe that
we are hitherto ignorant of the means of fepa-
rating them. The metallic calxes always
contain more or lefs phlogifton, and moft of
them alfo contain aerial acid, which they take
from the furrounding air in place of their
loft phlogifton, and pertinacioufly retain it;
yet fome calxes feem always to be free from
that acid, although precipitated by aerated
alkali : it is alfo certain that white arfenic
is free from it. But this doctrine will be
more fully illuftrated in another place. In
the mean time it appears from hence what
opinion is to be formed of the falts and ful-
phurs of metals, although the ideas of the
ancients upon this fubject occafion much
obfcurity.

Hence

Hence alfo it appears why earths and me-
tallic calxes fix arfenic. Nickel and cobalt
generally abound with arfenic, which can-
not be expelled by calcination alone; for
when a great part is diffipated by the force
of the fire, the reft either gradually lofes its
phlogifton and adheres like a fixed acid, or
is united by fufion with the metallic earths;
but powder of charcoal being added during
the calcination, immediately a large quanti-
ty of fmoke breaks forth, which fmells like
garlic, and is nothing elfe but the arfenical
acid reduced by phlogifton to the form of
a calx.

§ vi. *Properties of calcined Arfenic mixed by
the Via Sicca with other Subftances.*

(A) White arfenic fufes with the fame
metals as the regulus does, but in a manner
fomewhat different: it is true that no calx, as
fuch, can be united with metals; but ne-
verthelefs the calx of arfenic added to them,
when fufed in a crucible, readily unites with
them; but let it be remembered, that it is
reduced by the phlogifton of the fufed metal;
therefore, when the metal is an imperfect one,
fcoriæ alfo arife, confifting of the calcined
part of the metal and white arfenic.

(B) White arfenic injected into fufed
nitre excites a violent intumefcence and ef-
fervefcence, but without any fcintillation;
if this addition be continued until a new
2   portion

portion excites no motion, and the mafs be then well fufed, the product is called arfe- nic fixed by nitre. During this operation the nitrous acid is volatilized by the phlo- gifton of the metallic calx, and the arfenical acid, being difengaged, unites with the bafe of the nitre ; however, cryftals are not ob- tained, becaufe by means of the vehemence of the fire the alkali is fuperabundant ; but by a juft proportion of alkali and a due de- gree of heat cryftals may be produced ; for the vegetable alkali requires a flight fuper- abundance of arfenical acid in order to pro- duce cryftals ; this neceffary fuperabundance may alfo be preferved in a crucible, provided the fire be fo regulated that the bottom may be fcarcely red ; it fucceeds better however in diftillation.

The refidua of the diftillations, performed with an equal portion of prifmatic, cubic, or flaming nitre, all yield arfenicated alkali, which, after folution in water, may be cryf- tallized. It is vulgarly fuppofed that thefe cryftals cannot be decompofed by other acids, but erroneoufly. It is evident that though upon the addition of another acid the alkaline bafe unites with it, yet the acid of arfenic, being itfelf foluble, will yield no precipitation, nor even occafion a turbid- nefs ; from the want of turbidnefs nothing as yet has been eftimated but the cohefive force of the compound: but the error arifes from hence, that chemifts have fuppofed

U. 2   that

that white arfenic enters thofe falts, when in
reality it is only the acid. Therefore, in
order the more clearly to difcern the event,
we fhould diffolve the arfenicated vegetable
alkali (the neutral arfenical falt of Mr. Mac-
quer) in vitriolic acid ; this being done, let
the neutral falt be precipitated with highly-
rectified fpirit of wine, and wafhed, which
is very eafily done, for the vitriolated vege-
table alkali is not at all, and the arfenicated
vegetable alkali, but very fparingly, foluble
in this fpirit. The falt feparated in this
manner from the difengaged acid is foon
diftinguifhable, and in this inftance exhi-
bits all the properties of vitriolated vege-
table alkali : this, therefore, is undoubtedly
a decompofition of the arfenical falt by way
of folution ; here the alkali has no effect,
as it is itfelf unable to precipitate. But the
nature of thefe falts will elfewhere be more
accurately examined.

The digeftive falt, common falt, and fal
ammoniac, are not changed by arfenic ; the
reafon of which undoubtedly is, that the
marine acid is naturally loaded with phlo-
gifton.

(c) Corrofive fublimate, diftilled with
white arfenic, afcends unchanged, whatever
proportions be employed. Mr. Pott long fince
obferved, that in this cafe no butter of arfe-
nic arifes ; and certainly no fuch can arife,
as the calx of arfenic attracts the marine
acid with lefs force than the calx of the

10   mercury

mercury does. Let butter of arfenic mixed with calx of mercury be expofed to diftillation; at firft, before the whole can be decompofed, a little of the butter is elevated, but foon after a corrofive fublimate rifes, and finally a white arfenic.

(d) Fixed alkali with white arfenic melts in the fire almoft in the fame way as nitre, only the phlogifton flies off more flowly. Cauftic vegetable alkali, ignited in a clofe veffel, fixes about double its quantity of white arfenic; but the mineral alkali fixes nearly triple. Cauftic volatile alkali, drawn from white arfenic to drynefs two or three times repeatedly, becomes at length fo clofely united to it that the mafs bears fufion by means of fire.

Terra ponderofa and calcareous earth, fpoiled of the aerial acid by roafting, retain, on ignition in clofe veffels, about an equal quantity of arfenic; but magnefia, pure clay, and filiceous earth, fcarcely any.

(e) Sulphur eafily unites with white arfenic, reduces and mineralizes it; hence this compound always diffufes a moft penetrating odour of volatile vitriolic acid; for a portion of the fulphur yields to the calx of the arfenic a great quantity of phlogifton. See alfo § viii. ix. and x.

Saline hepar alfo diffolves white arfenic, but more readily attacks the regulus.

Equal quantities of fulphur, crude arfenic, and white arfenic, unite by fufion in a

U 3   clofe

clofe veffel, and generate the *lapis de tribus*, which is alfo called pyrmifon or arfenical magnet; this is red and fometimes tranf-parent.

§ VII. *Properties of calcined Arfenic mixed by Solution with other Subftances.*

(A) 80 parts of diftilled water, in an heat of 15°, diffolve one of white arfenic, and when boiling 15 parts of water are fufficient. But the arfenic, when once diffolved, is more eafily retained than taken up; fo that in a moderate heat 15 parts can hold one fuf-pended a long time; the fame is true of the other folutions. Solution of arfenic changes the deep tincture of turnfole to a red colour, but, like other metallic folutions, makes fy-rup of violets green; it is not changed by neutral falts, but is precipitated by moft metallic falts, and that in fuch a way that the metallic calxes, united with the arfenic, fall (though flowly) to the bottom.

It may be afked, whether the whole of the arfenic, or only the arfenical acid, unites with the metallic calx, yielding the phlo-gifton to the menftruum of the other metal? Certainly fuch a mutual commutation of principles does not appear improbable, if we confider only thofe cafes in which the men-ftruum is vitriolic or nitrous acid; but as iron (for example) united with marine acid (which does not attract the phlogifton of

white

white arfenic) as well as when it is joined to nitrous acid, is precipitated, it would appear that the whole of the arfenic is united, at leaft in certain cafes, to the metallic calxes.

(B) 70 or 80 parts of fpirit of wine, by means of a boiling heat, diffolve one of arfenic.

(c) Concentrated vitriolic acid, boiled with white arfenic, diffolves a fmall portion of it, which yet upon cooling it again depofits in the form of cryftalline grains : this vitriol diffolves in water with much greater difficulty than white arfenic itfelf ; expofed to the flame of a blow-pipe, it foon emits a white fmoke, but at the fame time is formed by fufion into a globule, which at firft bubbles, but foon grows quiet, and although of a white heat is but flowly confumed : the white arfenic quickly flies off, not being capable of enduring fufion, and much lefs ignition.

If the affufed acid be evaporated to drynefs, the repetition of this operation fixes the arfenic more and more, by carrying off the phlogifton, but fcarcely exhibits the arfenical acid pure.

The fame thing happens with the nitrous acid ; when diluted it diffolves the calx, which on cryftallization appears nearly under the form of white arfenic, but in its nature is a true middle metallic falt, which is difficultly foluble in water, and expofed to flame upon charcoal exhibits the fame phænome-

U 4

na with thofe exhibited by the vitriol of
arfenic above mentioned, but is confumed
fomewhat more quickly.

Concentrated nitrous acid deprives the
calx of its phlogifton more effectually; and
by a proper quantity, if evaporated to dry-
nefs, the calx may be brought to fuch a
ftate that the acid alone fhall remain. That
fubftance which is commonly called gum of
arfenic, is nothing but arfenic more or lefs
dephlogifticated, but always more fo than
white arfenic.

The marine acid contains phlogifton as
one of its principles, it therefore attacks
white arfenic in a different way: when con-
centrated and boiling it diffolves $\frac{1}{3}$ its own
weight, of which no fmall portion again
fpontaneoufly feparates upon cooling, but is
faturated with marine acid. This falt,
which may alfo be had in a cryftalline form,
is much more volatile than the former, nor
does it by any means endure ignition; in a
clofe veffel it all readily fublimes, and is
fparingly foluble in boiling water (§ ix. d.).
This folution is of a fine yellow, and
fcarcely differs from butter of arfenic ex-
cept in its degree of concentration. The
very nature of marine acid prevents the acid
of arfenic from being difengaged by its
means; which yet is eafily made to appear, if
to a folution of white arfenic in boiling ma-
rine acid, be added double the weight of
nitrous acid; the liquor being then evapo-
rated

rated to dryneſs, the arſenical acid will re-
main, which, in order to free it from any
foreign acid, ſhould be urged by fire until it
begins to be ignited: by this method 100
parts of white arſenic yield about 80 of dry
acid. In this operation the nitrous acid acts
more readily upon the phlogiſton of the
white arſenic than when it is poured on the
powdered arſenic; as in the former caſe the
ſolution effects a more perfect diviſion of the
arſenic: hence it alſo appears why white
arſenic is diſſolved in greater quantity, and
without any ſubſequent cryſtallization, by
aqua regia than by any other acid.

The phlogiſticated alkali precipitates
metals diſſolved in acids, yet leaves arſe-
nic nearly untouched, both in vitriolic and
nitrous acids, and in aqua regia; which
happens either from the ſmall quantity of
the matter diſſolved, or from its nature
being changed. From the marine acid it ſe-
parates arſenic of a white colour: in this
caſe error is carefully to be avoided, for the
ſolution may be precipitated by water alone,
unleſs the quantity of marine acid be large;
beſides, the diſengaged alkali, which is fre-
quently found in this lixivium, muſt be ſa-
turated by the acid.

Marine acid is dephlogiſticated by di-
geſtion with manganeſe, and is reſolved into
a red vapour, which in a cloſe veſſel ſpoils
a certain quantity of white arſenic, diſſolved
in water, of its inflammable principle, ſo that
the

the veſſel is found to contain ſeparately wa-
ter, acid of arſenic, and marine acid rege-
nerated ; the firſt of theſe may be obtained
alone by evaporation to drynefs.

The power of the other acids upon arſe-
nic has not yet been ſufficiently examined.
The acids of arſenic and of fluor diſſolve
it, and form cryſtalline grains ; and that
ſedative ſalt has the ſame effect I hardly en-
tertain a doubt ; although it muſt be con-
feſſed that borax, which is ſaturated with
that acid, does not precipitate arſenic dif-
ſolved in water. The acid of ſugar eaſily
takes up white arſenic, and yields priſmatic
cryſtals ; the ſame is nearly true of the acid
of tartar : vinegar, and the acids of ants and
of phoſphorus, alſo attack it, and yield cryſ-
talline grains, which are ſcarcely ſoluble in
water, nor have they yet been found to con-
tract any union with that fluid in the way of
deliqueſcence.

From what has been ſaid it appears plain-
ly, that ſolutions of arſenic made in acids,
in certain caſes depart from their uſual
nature ; which we have already ſhewn to be
owing to the adherence of the phlogiſton
being ſo looſe that the acid of arſenic is rea-
dily ſet at liberty.

(D) The fixed alkalis diſſolved in water
take up white arſenic ; and if by means of
heat they be loaded with it, a brown tena-
cious maſs is produced, which acquires ſo-
lidity, is of a diſagreeable ſmell, and is called
                                        hepar

hepar arfenici. The arfenic is partly preci-
pitated by mineral acids, though a portion of
it gradually lofes its phlogifton and adheres
more tenacioufly.

A folution made with volatile alkali
feems to effect this decompofition more rea-
dily, as no precipitation is occafioned in it
by acids.

(E) A limpid folution of faline hepar,
dropped gently into a folution of white ar-
fenic, floats, forming upon the furface a
grey ftratum, which at length difturbs the
whole of the liquor.

(F) White arfenic, diffolved in water by
the affiftance of heat, attacks fome metals,
particularly copper, iron, and zinc, nay the
two laft folutions yield cryftals by evapora-
tion. Thefe compounds are not vifibly
changed either by acid or alkaline fub-
ftances. Volatile alkali does not difcover
the copper by a blue colour, nor in the
martial folution does phlogifticated alkali
occafion any blue fediment. The caufe of
thefe phænomena is to be fought for in the
fuperabundance of phlogifton : for the acid
of arfenic takes up all metals ; united with
copper it is diffolved by the volatile alkali
with a blue colour, and joined with iron it
exhibits Pruffian blue in the ufual way : the
phlogifton which coagulates the acid into
white arfenic, is the fubftance which in
thefe mixtures conftitutes the only material
difference.

§ VIII.

§ VIII. *Mineralized Arfenic.*

We have already obferved that arfenic, both reguline and calcined, may be united with fulphur (§ III. VI). Nature fpontaneoufly produces thefe mineralizations yellow or red, fometimes pellucid and cryftalline; the yellow feem to affect a lamellated form, the red a prifmatic.

In the roafted heaps of arfenical ores, there frequently are found beautiful cryftals, partly tetraedral, partly octaedral, fome of which are hollow pyramids trigonal or tetragonal, each triangle being compofed of filaments refpectively parallel to the fides: thus an hollow trigonal pyramid, frequently filled up with leffer pyramids continually decreafing in fize, forms a tetraedrum; but 8 tetraedra, properly difpofed, form an octaedron. Thus in the via ficca is formed a ftructure entirely fimilar to that which common falt, digeftive falt, and perhaps all others, affume in the way of folution.

Iron at the fame time entering thefe mineralizations, renders the colour white, together with a polifhed and metallic appearance. To this clafs belong the ores, which are commonly called white or arfenical pyrites. Arfenic with fulphurated filver forms the red ore of filver, and with fulphurated filver and copper, the white or

grey

grey ore of filver; it appears to be only mechanically mixed with the cryftallized ores of tin, and the calcined ores of co-balt.

The fpecific gravity of orpiment is 5,315, but that of realgar about 3,225.

Orpiment and realgar fublime totally in a gentle heat, unlefs they be mixed with other fubftances; yet they fuftain fufion, and the former of them is thence made red. The arfenical pyrites yields a fublimate more or lefs white, in proportion to the quantity of fulphur; but the greater part of it does not fublime, but remains at the bottom.

§ ix. *Properties of mineralized Arfenic mixed by the Via Sicca with other Subftances.*

(A) Of thofe metals which readily unite with fulphur and arfenic, a certain quantity may be united with orpiment and realgar. We have already mentioned the ftone called pyrmifon (§ vi. e), and many other ores of this kind (§ viii.), which may alfo be artificially imitated. Silver, mineralized by fufion with orpiment, yields the red ore of filver. The reft may be formed ftill more eafily.

(B) Nitre is alkalized by mineralized ar-fenic, for it detonates partly with the ful-phur, partly with the arfenic, which when mineralized is always found in a form nearly reguline.

reguline. The alkali thus difengaged, either
forms a fal polychreft with the acid of the
fulphur, or unites intimately with the ar-
fenic (§ vi. d).

(c) Fixed alkali, added in proper quan-
tity, either to orpiment or realgar, and ex-
pofed to a fubliming heat, fixes the fulphur,
but difcharges the greateft part of the ar-
fenic ; yet the hepatic mafs retains a fmall
quantity of it, and if the alkali abounds,
fcarce any of the arfenic rifes.

(d) Orpiment, on diftillation with dou-
ble or triple its quantity of corrofive fubli-
mate, yields two liquids which refufe to
mix ; at length, on increafing the heat, a
cinnabar arifes. In the recipient, a butter
of arfenic is found at the bottom, pellucid,
of a ferruginous brown, which in the open
air at firft fends copioufly forth a vifible
white fmoke, and attracts the moifture of
the atmofphere, by which it is gradually
precipitated. The genefis of the butter has
been already explained (§ iii. d; vi. c); it
is very remarkable that it unites with marine
acid fo flowly, that they feem to repel one
another, nor can they be made to unite be-
yond a certain degree. Diftilled water added
to the butter precipitates a white powder,
which though ever fo well wafhed, retains
fomewhat of acidity ; for a portion of butter
of arfenic is yielded on diftillation ; a cir-
cumftance which is alfo true of Algarotti's
powder. The fmoke affects the organ of
                                                    fmell

finell with a peculiar penetrating odour, fomewhat refembling that of phlogifticated vitriolic acid, and depofits white flowers.

The fupernatant liquor, which authors compare to oil, is yellowifh and pellucid; with water and fpirit of wine it quickly feparates a white arfenical powder; is not difturbed by the ftronger acids; with alkalis it effervefces, and is precipitated. If it be kept in a cucurbit with a long neck, and unftopped, white flowers gradually concrete round the orifice; thefe are lax, and fometimes approaching to a cryftalline form. Finally, by fpontaneous evaporation pellucid cryftals appear at the bottom of the liquor, which are very difficultly foluble in boiling water, but when diffolved, precipitate filver from nitrous acid, and on the addition of an alkali, let fall fome arfenic. In lime-water a white cloud flowly furrounds them; expofed to the fire, they neither decrepitate nor lofe their tranfparency, but totally fublime without any arfenical fmell, which yet immediately appears, if ignited phlogifton comes into contact with them. No traces of mercury appear in this liquor, either by alkali or copper; undoubtedly, if any fublimate was prefent, it would remain in the water after the precipitation of the arfenic. Terra ponderofa, diffolved in marine acid, and dropped into this liquor, does not form even the

slighteft

flighteft congrumation, fo that there is no
vitriolic acid prefent.

From what has been faid it appears, that
the fupernatant liquor is no other than a
very dilute butter of arfenic, which, on ac-
count of the water, contains lefs arfenic.
The butter contains the acid in its higheft
degree of concentration, and therefore loaded
with a larger quantity of arfenic; the former
liquor will therefore be more abundantly
obtained, if the mixture of corrofive fub-
limate and arfenic be fet to ftand a night in
a cellar, or moiftened with water, before it
is fubjected to diftillation. As the common
marine acid can diffolve only a determinate
quantity of the butter, it follows, that what
remains after compleat faturation fhould
totally refufe to mix. Marine acid too much
diluted precipitates the butter; but in pro-
portion as it is ftronger, it diffolves a greater
quantity.

§ x. *Properties of mineralized Arfenic*
     mixed by Solution with other Subftances.

(A) Water has no effect on mineralized
arfenic.

(B) The acids operate according to cir-
cumftances, efpecially the nitrous acid and
aqua regia; the former menftruum, if con-
centrated, foon deftroys the red colour of
realgar, but does not affect the yellownefs
                                          of

of orpiment, for its primary action is to calcine the arſenic, which in realgar muſt neceſſarily change the red colour to a yel-low.

Aqua regia, by long digeſtion, takes up the arſenic, but ſo as to leave the ſulphur alone at the bottom ; hence we may diſco-ver the propertion of ſulphur to arſenic. But this operation muſt be ſkilfully performed, leſt on the one hand, by the inertneſs or inſufficient quantity of the menſtruum, ſome part which ſhould be taken away re-main untouched ; or, on the other, leſt that portion which ſhould remain entire be di-miniſhed. The colour of the reſiduum ought to be altogether grey, for ſo long as any yellow particles remain mixed with it, ſome of the arſenic alſo remains. By too much heat, or too long boiling, eſpecially if the nitrous acid be ſtrong, more or leſs of the ſulphur is alſo deſtroyed; for the nitrous acid takes away the principle of in-flammability from the vitriolic, ſo as to ſet the latter at liberty.

If iron be preſent in the mineralization, it is all diſſolved in virtue of its ſuperior attraction before the arſenic is acted upon, unleſs it be too much calcined during the operation, either by heat, by the acceſs of air, or by the great power of the men-ſtruum.

The red ore of ſilver is compleatly de-compoſed by aqua fortis, which takes up

the filver and the arfenic, fo that the fulphur alone remains at the bottom ; by this method, 100 parts of the tranfparent cryftals yield about 60 of filver, 27 of arfenic, and 13 of fulphur ; iron is not always prefent.

The white ore of filver, firft treated with aqua fortis, lets fall the filver and copper, and then yields the remainder of the arfenic to aqua regia, fo that at length the fulphur may be obtained pure : the diffolved filver may be precipitated by copper.

(c) Cauftic fixed alkali, boiled in water with orpiment, yields a fœtid hepatic folution, called by fome a fympathetic ink.

Orpiment boiled in water, with double the weight of quick-lime, affords a liquor which may be employed for proving wines ; in this cafe the hepar calcis operates. Thefe folutions, upon the addition of acids, depofit both the fulphur and the arfenic.

(D) Oils too, affifted by heat, diffolve both orpiment and realgar.

§ XI. *Ufes of Arfenic.*

Concerning the ufes of this metallic fubftance, we can only treat in a very flight way.

It can hardly be doubted but that it may be applied to valuable purpofes in medicine, and experiments have long fince put that matter entirely out of doubt ; but with

refpect

respect both to its dose and preparation, the utmost caution is necessary. From the properties disclosed by the foregoing experiments, it appears that this most virulent of all poisons acts in the manner of an highly corrosive acid, and that even externally (§ v.). Since then phlogiston and alkalis are the most powerful correctors of acid acrimony, it will readily occur how it may be mitigated, and its deleterious effects obviated. Hence too it appears why realgar is less noxious, why the regulus is milder than white arsenic, and this again milder than the dry acid; and why the baths of Carlsbad, which contain a mineral alkali only, united with aerial acid, are extremely useful in diseases occasioned by arsenic: why arsenic, taken internally without the necessary correction, occasions by its irritating quality convulsive motions, among other symptoms, both in the stomach and other parts of the body. To pass over other matters, which from the chemical analysis of arsenic might be useful in the practice of medicine, this only I add, that of all the metals arsenic most easily loses its phlogiston (§ 11.); therefore we should be cautious in confiding to phlogistic correctors, as the phlogiston may be separated in the viscera by many different ways. The instance of a man poisoned by arsenic, who was dissected in the anatomical theatre at Upsal, shewed that the penetrating garlic smell may be

X 2   excited

excited fimply by a tendency to the putre-
factive fermentation.

The pfilothrum turcicum contains orpi-
ment, among other fubftances ; but its de-
pilatory power is perhaps more properly
afcribed to the cauftic alkali.

Philofophers are wont to evince the ex-
traordinary porofity of bodies, and the won-
derful fubtilty of vapours, by the fympa-
thetic ink (§ x. c.) ; for writing made with
vinegar of litharge, by itfelf invifible, ex-
pofed to the vapour of this liquor, becomes
in a few minutes of a brown colour, even
though a great many folds of paper be in-
terpofed.

Wines naturally acid, or grown fo by
age, ftill continue to be edulcorated by lead,
notwithftanding the punifhments attending
the detection of this fraud : it is therefore
of great confequence to be in poffeffion of
an eafy method of difcovering fuch a fo-
phiftication. For this purpofe the proba-
tory liquor (§ x. c.) is commonly employ-
ed ; for this, when dropped into pure wine,
occafions nothing but a yellow precipitate,
but when the wine is adulterated, a brown
or black. This may alfo be done by a
faline hepar ; but fraud and avarice have
contrived methods of eluding this proof,
unlefs chemiftry lend its affiftance ; for if a
fmall quantity of chalk be contained in the
wine, the faline hepar fails, for the white
calcareous earth falling, diminifhes the
                                    blacknefs.

blackneſs. A large proportion of tartar, renders the probatory liquor ineffective, as the tartareous acid forms with the lime a white ſalt very difficult of ſolution.

Arſenic ſometimes enters metallic com-poſitions, eſpecially copper and tin ; but it is much to be wiſhed that ſuch compoſi-tions were baniſhed, at leaſt from the kitchen. Shot made of lead is ſometimes hardened by orpiment.

Regulus of arſenic enters into the compo-ſition of Meuder's phoſphorus. The power of the calx in vitrification was long ſince known to Geber, and therefore it is fre-quently employed in glaſs-houſes, either for facilitating fuſion, for acquiring a certain degree of opacity, or, finally, for carrying off phlogiſton. The method in which mountain cryſtals, placed over orpiment, white arſenic, crude antimony, and ſal am-moniac, mixed in a crucible, are tinged by means of heat, is deſcribed by Neri, and upon trial this is found to be true ; I have thus obtained theſe cryſtals beautifully marked with red, yellow, and opal ſpots, but at the ſame time cracked, which could ſcarcely be avoided.

In painting too the artiſts ſometimes em-ploy arſenic. Painters in oil frequently uſe both orpiment and realgar ; and it is pro-bable that wood covered with a pigment mixed with white arſenic, would not be liable to be ſpoiled by worms. A moſt

X 3 beautiful

beautiful green pigment may be precipitated from blue vitriol, by means of white arfenic diffolved in water, together with vegetable alkali; this, prepared either with water or oil, affords a colour which fuffers no change in many years. The playthings of children, however, fhould not be painted with this or any other preparation of arfenic, on account of their cuftom of putting every thing into their mouths.

DISSERTATION XXII.

OF THE

ORES OF ZINC.

§ 1. *Historical Introduction.*

THE femi-metal, which at prefent is
called Zinc, was not known fo much
as by name to the ancient Greeks and Ara-
bians. The name which it bears at prefent
firft occurs in Theophraftus Paracelfus (a) ;
but no one as yet has been able to difcover
the origin of this appellation. A. G. Agri-
cola calls it contrefeyn (b) ; Boyle, fpel-
trum (c) : by others it is denominated fpe-
auter, and Indian tin (d). Albertus Mag-

(a) In operibus, paffim.
(b) De re metallica.
(c) Ponderab. flammæ.
(d) Fœda trifida chymica.

X 4   nus,

nus, more properly called Bolſtadt, who died in 1280 (e), is the firſt who makes exprefs mention of this ſemi-metal. He calls it golden marcaſite, aſſerts that it approaches to a metallic nature, and relates that it is inflammable. However, as zinc is white, the name of golden marcaſite is not very proper; it would therefore appear probable, that it derives that name from the golden colour which it communicates to copper, had not Albertus exprefsly ſaid, that copper united with golden marcaſite becomes white; but he has probably either miſunderſtood or miſrepreſented what he had heard related by others. It may alſo happen that zinc was formerly thought to contain gold. J. Mattheſius, in 1562 mentioned a white and a red zinc (f); but the yellowneſs and redneſs are only to be underſtood of the ores. Hollandus, Baſil Valentine, Aldrovandus, Cæſius, Cæſalpinus, Fallopius, and Schroeder, obſerve a profound ſilence on that head (g).

The eaſtern Indians have long ſince been in poſſeſſion of the method of extracting pure zinc from the ore, at leaſt, in the courſe of the laſt century. This metal was brought from thence to Europe. Jungius mentions the importation of zinc from In-

(e) In libro mineralium.
(f) Sarepta.
(g) Pott on Zinc.

dia,

dia, in 1647 (*b*) : a metal of this kind, under the name of tutenag, is ftill brought from thence, which muft be carefully diftinguifhed from the compound metal of that name. G. E. van Lohneifs tells us, in 1617, that a long time before zinc had been collected by fufion at Goflar (*i*). It has been long ufual to form orichalum from the ores of zinc by the addition of copper ; but it does not yet appear at what time this art was invented. Pliny makes mention of the orichalum, as alfo of three fpecies of Corinthian vafes, one of which is yellow, and of the nature of gold (*k*). Erafmus Ebner of Norimberg, in the year 1550, was the firft who ufed the cadmia of Goflar for this purpofe.

In the year 1721, Henckel indeed mentioned that zinc might be obtained from lapis calaminaris by means of phlogifton, but he conceals the method (*l*). The celebrated Anton. van Swab. in 1742, extracted it from the ores by diftillation, at Wefterwick in Dalecarlia (*m*). It was determined to found a work for the purpofe of extracting larger quantities of this femi-metal ;

(*b*) De mineralibus.
(*i*) Bericht von Bergvercken.
(*k*) Hift. Nat. xxx. c. 2.
(*l*) Pyritologia.
(*m*) Elogium magni hujus metallurgi coram, R. Acad. Stock. recitatum.

but

but afterwards, for various reasons, this project was laid aside ; therefore the illustrious Margraaf, not knowing what had been done by the Swedish mineralogists, in the year 1746 published a method of performing this operation, which he had discovered himself (*n*).

It is not known how zinc is extracted in China. A certain Englishman, who several years ago took a voyage to that country for the purpose of learning the art, returned safely home, indeed, and appears to have been sufficiently instructed in the secret, but he carefully concealed it. We find afterwards that a manufactory had been established at Bristol, where zinc is said to be obtained by distillation per descensum. We have already seen that it had been before obtained in Sweden by distillation per ascensum, which afterwards was effected in larger quantity, by Meff. Cronstedt and Rinman, two very celebrated mineralogists and metallurgists.

The difficulties occasioned by the volatile and combustible nature of this metal, for a long time retarded the knowledge of the ores containing it ; nor is that wonderful, as, being of a metallic form, it has even to our times been considered as composed of two or three ingredients. Albertus Mag-

(*n*) Mem. de l'Acad. de Berlin.

nus

nus thinks iron an ingredient ; Paracelfus called it a fpurious fon of copper ; Lemery holds it to be a fpecies of bifmuth ; Glauber, and many alchemifts, confider it merely as an immature folar fulphur ; Homberg, as a mixture of tin and iron ; Kunckel, as a coagulated mercury ; Schluter, as tin, made brittle by fulphur, &c.

The ore, which refembles true galena, is called pfeudo galena ; and is for that reafon, perhaps, by the inhabitants, called blende, as in texture and fplendor it refembles the blends, though it contains no filver. The celebrated Brandt, in 1735, fhewed that this contained zinc (o) ; and foon after D. Swab actually extracted it from the Bolognian pfeudo galena, which poffeffes a metallic fplendor. The Baron Funch, in 1744, determined the prefence of zinc in pfeudo galena from the flame and the flowers (p) ; and in 1746 Mr. Margraaf fet the matter out of doubt.

Zinc cannot be united with fulphur alone, yet is found joined with it in the pfeudo galena ; and this conjunction Mr. Cronftedt (q) thinks is effected by means of iron ; but Mr. Sage (r) fuppofes that in this inftance an earthy hepar is formed by means of lime.

(o) Act. Upfal.
(p) Act. Stockholm.
(q) Cronftedt Mineralog.
(r) Mem. de l'Acad. de Paris, 1771.

Julius,

Julius, in the year 1570, undertook, at Rammelfberg, the preparation of a certain falt, which he called Ertz-alaun, but which we now meet with under the name of Gallizenftein. No one, before 1735, knew the true compofition of this falt; but about that time D. Brandt publifhed two obferva- tions explaining its nature; for he found that this falt calcined, and then treated with charcoal-duft and copper, formed brafs; and alfo that zinc, directly diffolved in vi- triolic acid, formed a falt of the fame na- ture as gallizenftein. In the fame year Mr. Hellot communicated the latter of thefe ex- periments, made by himfelf, to the Royal Academy at Paris, proving that white vitriol is a middle falt compofed of zinc and vitrio- lic acid.

Mr. Sage has lately attempted the analyfis of lapis calaminaris, in which he afferts that zinc is mineralized by marine acid. The fame author contends that zinc is found in manganefe (f); and Dr. Bayen relates that he difcovered it in the white ores of iron (t): but they have both miftaken manganefe for zinc (u).

(f) Mem. de l'Acad. de Paris, 1770.
(t) Journal de Phyfique, par Mr. Rozier, 1776.
(u) See the Treatife on the White Ores of Iron.

§ II. *Zinc*

§ 11. *Zinc is presented to us by Nature under a Variety of Forms.*

It is not yet certain whether zinc be ever found native, unlefs we fuppofe the grey, flexible, metallic, inflammable filaments, furrounded by yellow ochre, which Mr. de Bomare obferved in the neighbourhood of Limburg and Rammelfberg, to be produced folely by the hands of nature (x). In order to difcover their true origin, they muft be attentively confidered, and their nature folicitoufly inveftigated in the matrixes. In the mean time, it will be proper briefly to defcribe the habitudes of perfect zinc, when expofed to flame upon charcoal. This femi-metal fcarcely melts alone by the blow-pipe, as its whole furface is quickly covered with a calcined cruft; but the internal mafs, fufed and expofed to ftrong heat, now and then explodes with a beautiful greenifh blue flame, and difperfes a white calx.

A fmall piece of zinc is taken up with effervefcence by microcofmic falt in fufion; at the fame time it fends forth many flafhes, with a crackling noife; but if the heat be too great it explodes, fcattering about ignited particles.

(x) De Bomare, Mineralogie.

Borax

Borax takes up zinc with a degree of effervescence, and the fufed regulus at firft tinges the flame ; if the blaft be intermitted it fends forth a flafh, and afterwards it is difficult to reproduce the phænomena ; but the regulus is gradually diminifhed, and the mafs of borax fpreads upon the charcoal without any explofion.

The mineral alkali, expofed to heat with zinc, in a filver fpoon, corrodes it, but without any tinged flame, or any explofion (y).

The ores containing zinc differ much in appearance and properties ; but fo long as the uncertainty of the exiftence of native zinc remains, they may, agreeably to their nature, be divided into two claffes, fome containing the femi-metal fimply deprived of phlogifton, the others holding it mineralized, either by fome acids, or united to fulphur by the means of iron.

Calcined Zinc.

(A) Pure zinc, calcined in difcrete particles, is extremely rare. To this we may refer the zinc brought from China by Grill, and defcribed by Von Engeftrom in the year 1775 (z).

(y) The Chinefe zinc, upon examination, yields fcarcely half a pound of lead in an hundred. The zinc of Goflar contains fomewhat more ; but neither the one nor the other yields the fmalleft particle of iron.

(z) Act. Stock. 1775.

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That

That the comparison with native zinc may be more easily made, it will be necessary to describe briefly the habitudes of flowers of zinc, as examined by the blow-pipe. These flowers, exposed alone to the flame on charcoal, put on a phosphoric splendor, which vanishes when the flame intermits: they also remain fixed and refractory.

With microcosmic salt they are readily dissolved without spumescence: upon cooling, the globule remains transparent, if the zinc amounts to less than double the bulk of the salt; if to more, the globule is milky. In proportion as it is more saturated, it adheres the less to the charcoal.

With borax the same thing happens, but the flowers are more slowly taken up; and in proportion as the globule is more loaded, it expands more upon the charcoal.

In a silver spoon, with mineral alkali, they suffer no sensible change.

(B) Calcined zinc, mixed in various proportions with earthy and ferruginous particles, commonly called *lapis calaminaris*, is employed in the composition of brass: it is of a ferruginous, yellow, or white colour, and generally hard; but the hardness is not the same in all, nor is it sufficient to strike fire with steel.

These minerals exhibit with the blow-pipe the same phænomena as the preceding varieties, except those which abound in
iron;

iron ; for the fubtile powders of thefe laft, expofed to a white heat, are of a more obfcure colour, and are magnetic (*a*). The microcofmic falt contracts with them the colour of fmoked glafs ; borax a yellowifh green ; but in both cafes, if too much ore be added, an opacity is produced. The mineral alkali grow black.

Mineralized Zinc.

Zinc aſſumes appearances foreign to its nature, in the hands of nature, partly by its union with a certain native acid, partly by means of fulphur. Among the acids which mineralize zinc, no other are yet known but the aerial and the vitriolic.

Aerated zinc is found concreted fo hard, as fometimes to ſtrike fire with ſteel ; it exhibits an appearance like quartz, upon breaking, and is on the furface generally knotty, ramous, or variouſly contorted into lamellæ : this is called glaſs of zinc. And Mr. von Swab obferved, during diftillation, that a matter, exactly of the appearance above defcribed, was produced through the fmalleſt cranny in the apparatus.

A variety of this mineral, brought from England, expofed to flame with the blow-

(*a*) The celebrated Rinman, after calcining the white lapis calaminaris of Aix-la-Chapelle for the ſpace of eleven days, in one of the furnaces ufed for the preparation of ſteel, found that it adhered to the magnet almoſt in the fame manner as filings of iron.

pipe,

pipe, remained without liquefaction, but cracked, was as it were refolved into flowers, and acquired a more dilute colour. The fmell fhews no traces of fulphur, nor is it magnetic either before or after calcination. The microcofmic falt, and alfo borax, diffolve it without difficulty; the latter fomewhat more flowly. The mineral alkali fcarcely takes up any, fo that its habitudes much refemble thofe of the flowers.

Artificial vitriform zinc manifefts the fame properties as the natural, but does not fplit, and is more flowly and fparingly diffolved in the ufual falts.

(B) To this clafs alfo muft be referred the variety which is foluble in water by means of vitriolic acid. Mineralogifts very properly enumerate this among the metallic falts; yet it muft not be paffed over in a place where our intention is to fpeak of all the minerals which contain zinc abundantly.

Pure vitriol of zinc, expofed to the flame, on fufion foams violently, and, finally, leaves behind a refractory mafs, which does not grow phofphoric like the flowers.

This vitriol, calcined, is readily taken up with effervefcence by the microcofmic falt: if too much of the vitriol be added, the globule is of an opal colour. The fame takes place with borax. It unites at firft with mineral alkali, with violent effervef-

VOL. II.   Y   cence;

cence; but afterwards is very little acted upon.

Native vitriol of zinc is scarce ever found pure, but mixed with copper or iron, or both; so that the phænomena vary in respect both of the quantity and quality of the heterogeneous mixture.

Zinc, mineralized by sulphur, produces various colours. I have known it black, brown, yellow, greenish, and, finally, with a metallic splendor; which last is called by Mr. Cronstedt, particularly, the ore of zinc. The pseudo galena puts on a squamous form, not unlike that galena which shines when the little lamellæ are viewed obliquely. Sometimes it is found semi-transparent, very rarely octaedral; it occurs accidentally, mixed with silver, lead, copper, arsenic, and other metals.

The habitudes vary a little, according to the different heterogeneous matters. For example, we shall describe three varieties found in Sweden; *viz.* the black of Dannemer, the red of Sahlberg, and the metallic one of Boval.

The first of these does not strike fire with steel, yields a brown powder which decrepitates upon heating, sends forth a smoke of a sulphureous smell, and deposits upon the coal partly white flowers (consisting of zinc), and partly yellow ones (consisting of lead): it is not magnetic, either crude or roasted:

when

when expofed to the flame, in fuch a man-
ner that the divided apex of the flame is
reflected, it frequently appears tinged with
zinc.

· The fecond is little changed by· pulve-
rization ; it ftrikes fire with fteel on account
of the quartzofe matrix ; it neither decrepi-
tates nor fmokes, and generates flowers
but fparingly ; yet it fometimes tinges the
flame.

The third produces an afhen brown pow-
der ; does not decrepitate ; expofed to the
apex of the flame, it exfudes fmall drops,
and difperfes flowers.

The microcofmic falt diffolves the firft,
and at the beginning puts on an opake
whitenefs ; but when nearly an equal bulk
is added, it grows black. The fecond is
never entirely taken up, for the quartzofe
part of the matrix remains ; when loaded,
the globule grows milky. The third is dif-
folved with little effervefcence, and the
globule is obfcured, is a little blue (from the
copper) ; but by long fufion the tinge va-
nifhes ; if continued too long, it is rendered
opake.

It is to be obferved of each of them,
that during folution flafhes break forth,
fuch as are defcribed proceeding from
the metallic zinc, but fmaller and lefs fre-
quent.

Borax, with a fmall quantity of the firft,
grows yellow, with a larger quantity black,

and

and that almoſt without any effervefcence.
The fecond is more flowly taken up, yield-
ing a yellowiſh green glafs : by too much
an opacity is contracted.

Mineral alkali attacks the firſt with vehe-
ment ebullition, producing grains of lead,
although no galena appears mixed with it
even by a glafs. The fecond is alſo taken
up with effervefcence, forming an hepatic
mafs, which is alfo true of the third ; but
thefe yield no metal.

§ III. *Analyſis of calcined Zinc.*

We fhall now examine a variety of lapis
calaminaris, which, in the manufactories
where brafs is prepared, is called Hungarian
lapis calaminaris.

(A) 100 lb. of this ſtone, to which were
added 165 of concentrated vitriolic acid,
generated fo great a degree of heat, as to
raife the thermometer in a few moments
from 15° to 65°, and a white fmoke breaks
forth, which yet could not pafs through the
tube of an alembic without the affiftance of
fire. This fmoke, collected in diſtilled wa-
ter, exhibited the fame phænomena as are
mentioned in the following paragraph, and
therefore is of a vitriolic nature (§ IV. D).

(B) 100 parts of this mineral, well cal-
cined, lofes fcarcely any of its weight ; fo
that if it contains any aerial acid, the quantity
is fo fmall as not to be fenfible on weigh-
ing ;

ing; for the fmall obfervable decrement
muft be afcribed to the humidity. The fame
is alfo confirmed by folution in acids, for
no effervefcence appears in this operation.

(c) A double weight of nitrous acid was
poured upon 100 of the fame ore, which
being evaporated to drynefs, the fame quan-
tity was twice more added, and in like
manner expelled by fire; this was done that
the iron being calcined might remain info-
luble: during this operation the vapours
were fomewhat red.

The mafs being again put into nitrous
acid, the zinc alone was diffolved by phlo-
gifticated alkali, and a white fediment was
precipitated, which, when wafhed and dried,
weighed about 359 lb. The infoluble refi-
duum, well elixated and dried, weighed near-
ly 16 lb.; this, with three times its weight of
concentrated vitriolic acid, was evaporated to
drynefs in a fand bath; a folution was then
extracted with diftilled water, which yielded,
by means of phlogifticated alkali, about
12 lb. of Pruffian blue: the liquor remain-
ing produced, by fubfequent cryftallization,
a true alum, but in very fmall quantity.

Finally, there remained 12 lb. which
eluded the force of the acids, and which
was of a filiceous nature.

(D) All thefe being confidered, there are
found in 100 of this lapis calaminaris, 84 of
calcined zinc, 3 of calcined iron, about 1 of
pure clay, and 12 of filiceous earth.

Y 3   (E) This

(E) This analysis has also been conveniently performed in another way: first, by abstracting vitriolic acid, then elixating with water, finally precipitating by caustic volatile alkali, and dissolving. The residuum, which resists the vitriolic acid, is siliceous earth; that which refuses the volatile alkali contains a calx of iron with pure clay, which, when dissolved in vitriolic acid, may be separated by phlogisticated alkali.

(F) We shall finish by adding somewhat here concerning the calx of zinc, artificially prepared, which commonly goes by the name of flowers of zinc. These are easily and totally dissolved by acids, generally without any motion, but sometimes with a vehement effervescence. Some flowers, which had been made by Von Swab in the year 1742, were quietly dissolved after the space of thirty-seven years; whereas others, made in 1758, excited a violent effervescence like chalk, insomuch that one would be induced to suppose at first that chalk was mixed with them; but upon examination nothing heterogeneous was found. The elastic fluid which was extricated shewed, upon examination, all the properties of aerial acid. This difference is undoubtedly occasioned by the quantity of the aerial acid surrounding the mass during calcination, and shews that the dephlogistication may be effected without the reception of that acid.

The

The flowers, which are extremely white, expofed to the action of dephlogifticated marine acid for fome days in a clofe veffel, grow almoft black, but are not (like white arfenic) refolved into an acid liquor.

§ iv. *Analyfis of aerated Zinc.*

The fpecimen of aerated zinc firft examined, was that brought from Holy-Well in England, the fame which had been examined before by the blow-pipe (§ ii.)—Of this

(A) 100 lb. reduced into a fubtile powder, loft by calcination 34 lb. but did not betray the flighteft traces of a fulphureous odour.

(B) As it diffolves in marine acid with effervefcence, and without any hepatic odour, the operation was performed in a chemico-pneumatic apparatus, in order to examine the nature of this volatile vapour. 100 lb. in this way yielded only ten cubic inches of elaftic fluid; but the water through which it paffed, amounting to 30 inches, was found almoft faturated. In order therefore to determine it more accurately, it was collected in mercury, and exhibited about 28 cubic inches, which were all abforbed by diftilled water, and imparted to it all the properties communicated by aerial acid. Now 28 cubic inches of that acid, in a moderate temperature, weigh about fo many affay pounds, but in calcination 34 are loft;

fix

fix therefore remain, which doubtlefs are owing to water, for it appears from (D) that no aerial acid is prefent.

(c) The experiment was repeated in the fame way, but the vitriolic acid employed inftead of the marine; an equal bulk of aerial acid was produced.

(D) In order to difcover whether any veftiges of marine acid remain hid in this ore, to 100 parts, reduced into a very fubtile powder, were added 165 of concentrated vitriolic acid, in a fmall cucurbit fitted with an head, the orifice of whofe tube was plunged under diftilled water. No fmoke or fmell was perceived. The cucurbit was therefore placed in a fand bath, and fire being applied, the mixture at length fent forth a white fmoke, which, paffing through the water, there depofited whatever acid it contained, and the water loaded with this fume reddened paper tinged with turnfole. Some drops of a folution of nitrated filver were dropped into a fmall portion of this, upon which clouds arofe, but thefe quickly vanifhed upon the addition of a quantity of diftilled water. But as vitriolated filver is much more foluble than falited filver, a fufpicion arofe of the prefence of vitriolic acid, which was further confirmed by the dropping in of nitrated mercury prepared without heat; for the white ftriæ which appeared upon this inftillation, upon the further addition of a large quantity of water fell to the

bottom

bottom in the form of a yellowish powder: besides, the addition of salited terra ponderosa to another portion, immediately generated a spathum ponderosum, the most certain sign of vitriolic acid. If therefore marine acid be present in some vitriform ores of zinc, this must be considered at least as accidental, and by no means necessary to their composition.

(E) Vitriolic acid takes it up almost entirely, leaving scarcely 00,1 remaining undissolved; and evaporation being continued to dryness, so as to expel the superfluous acid, the solution, on the addition of water, yields by crystallization 326 lb. of white vitriol.

(F) Phlogisticated alkali, added to a solution of this vitriol, throws down a mixed mass, white and spongy, yet containing a few particles of Prussian blue; which shews that a small quantity of iron is present. It is worthy of observation, that the blue atoms gradually become of a brownish red; whether they be suffered to remain in the liquor for some days, or whether they be separated by filtration, washed, and dried.

(G) 100 parts of vitriform zinc, with powdered charcoal, and 150 of copper, treated in the usual way, communicated to the copper an increment only of 15 lb. though in this operation a great part of the zinc always is destroyed by deflagration.

(H) Upon

(H) Upon comparing all the experiments, it plainly appears, that in 100 of this English mineral there are 28 of aerial acid (B, C), 6 of water (B), and of calcined zinc (with a very small portion of ochre scarce exceeding 1) about 65 (E, F).

(I) For the sake of comparison it must be added, that the artificial glass of zinc, arising from the distillation of this semi-metal, dissolves in acids without any effervescence; so that it also contains more zinc, and the other variety mentioned in § 11. (B) is produced.

§ v. *Analysis of vitriolated Zinc.*

Zinc, in a saline state, has hitherto been but rarely found, and always united with vitriolic acid; scarcely ever pure, but united with vitriol of iron or of copper, or both together. We shall therefore first examine it in its pure state, in order to discover occasional differences the better.

(A) Vitriol of zinc yields transparent crystals, clear as water, and without any colour; they exhibit compleat quadrangular prisms, two of whose opposite sides are broader; the terminating pyramid has also four sides: in general, however, in the two opposite angles of the prism, a small defect is observed, so that the section becomes hexagonal. The native vitriol is generally stalactitic, arising from the spontaneous calcination

nation of pfeudo galena. The cryftals rather
calcine than deliquefce.

(B) By gentle calcination 100 lofes about
40, which confift of water.

After a white heat of three hours, no more
remained than 20 of afhen brown coloured
powder ; yet that metallic zinc, by calcina-
tion, is encreafed at leaft 0,17, plainly ap-
pears, for 20 of calx are produced from little
more than 17 of the metal : 100 of white
vitriol therefore contains 20 of calcined
zinc, 40 of vitriolic acid, and 40 of the
water neceffary to cryftallization.

(c) In a moderate temperature 100 of the
cryftallized vitriol require to diffolve them
228 of diftilled water. By a boiling heat
much more is taken up.

(D) If to a folution of the 100 juft men-
tioned, be added a phlogifticated alkali,
whitifh particles are foon feparated ; which,
collected, wafhed, and dried, after compleat
precipitation, yield 83 of a yellowifh white
powder. Now, 1 part of metallic (that
is 1,17 of calcined zinc) yields to phlo-
gifticated alkali nearly 5, therefore 83 indi-
cate $16\frac{3}{5}$ of metallic zinc ; which agrees al-
together with an experiment already tried in
another way (B).

(E) A folution of 100, precipitated by
aerated alkali, yields a white powder, in
weight 38, which is taken up by acids with
an effervefcence which continues till the
very laft particle is diffolved ; therefore 20

of

of calcined zinc are able to fix 18 of aerial acid and water together. Hence we derive an illuftration of what has been already faid concerning its effervefcence in acids (§ IV. F.). Zinc, when once calcined without aerial acid, afterwards attracts it fcarcely at all, or at leaft very flowly.

(F) White vitriol, mixed with green, blue, or both, cannot be feparated from them by cryftallization.

The mixture may in fome degree be judged of by the colour. The form of the cryftals is fpathaceous, even though the inquinament does not exceed $\frac{1}{4}$. The phlogifticated alkali betrays copper by a brownifh red, and iron by blue particles, the former of which, particularly, diftinctly appear on the firft inftillation, mixed with the white, provided the liquor be not fhaken. On the addition of zinc, both the copper and iron are precipitated.

§ VI. *Analyfis of the black Pfeudo Galena of Dannemer.*

I have tried by various methods to difcover the compofition of the pfeudo galena, but fhall here only mention thofe which feemed peculiarly adapted to the purpofe in each particular cafe.

(A) By a white heat of four hours, 25 out of 100 flew off; at the fame time a ftrong fmell of fulphur was perceived, fcarcely
mixed

mixed with that of arſenic, but no flame, nor were any flowers of zinc diſcernible; the colour of the roaſted powder was like that of bricks.

This operation being finiſhed, the quantity of volatile matter is generally eſtimated from the decrement of weight; but when we are examining ores by this method the quantity is made leſs than it ought, as metals gain weight by calcination. Lead gains about 0,12, copper 0,16, zinc 0,17, and iron 0,36. In the preſent caſe, the quantity of the metals otherwiſe known (if they be ſuppoſed in a perfect ſtate) ſhews that by the dephlogiſtication the weight of the remaining maſs is encreaſed by 12. This correction therefore ſhould not be neglected.

(b) Six hundreds of the pſeudo galena being expoſed to heat in a cloſe apparatus, no elaſtic fluid appeared; a little ſulphur was ſeparated, and nearly 6 lb. of reguline arſenic collected in the upper part, as alſo about 36 of water in a tube fitted for receiving it; viz. to the extremity of the alembic tube, turned upwards, was faſtened a wet bladder well emptied of air by preſſure: during the operation it was a little inflated, but on cooling collapſed again; the water filled the tube; the reguline arſenic covered the upper part of the cucurbit with a black ſcale.

(c) As lead is found in this ore (§ 11.), the 75 parts remaining were boiled in marine acid ſo long as any thing was diſſolved; to

the

the folution, filtered, and infpiffated by eva-
poration, was added vitriolated volatile al-
kali, by which a vitriol of lead was partly
feparated inftantly, and partly by further
evaporation. This vitriol yielded about 6 lb.
of lead.

(D) The remaining liquor was evaporated
to drynefs; and, for the purpofe of calcining
the iron, nitrous acid was repeatedly evapo-
rated from it, the laft time even to ignition.
Finally, it was diffolved in that acid; but
there remained 13 of calcined iron, which
is equivalent to about 9 of the metal.

(E) A folution of zinc, precipitated by
phlogifticated alkali, yielded a whitifh yel-
low fediment, weighing 223 lb. which in-
dicate nearly 45 of metallic zinc (§ v. D).

(F) The marine acid mentioned in (B)
was refifted by 4 parts, which diffolved with
great difficulty in microcofmic falt, but
more eafily in borax, and in mineral alkali
with effervefcence: thefe properties indicate
a filiceous nature.

· (G) Upon a juft calculation, therefore, it
appears, that the 100 under examination
contains 29 of fulphur, 1 of regulus of arfe-
nic, 6 of water, 6 of lead, 9 of iron, 45 of
zinc, and 4 of filiceous earth. There is no
doubt but that the proportions vary a little
in the various fpecimens: befides, in order
to determine all the quantities with pre-
cifion, it would be neceffary to know the
deficiency of phlogifton occafioned in me-

10   tals

tals by their union with fulphur; a circum-
ftance which however is yet unknown:
fomewhat is certainly loft, but it fhould ap-
pear the lofs is but fmall.

§ VII. *Analyfis of the brown Pfeudo Galena of
Sahlberg.*

(A) The brown pfeudo galena of Sahl-
berg, properly roafted, lofes only 0,13,
of which 5 are water. The fulphureous
odour is lefs perceptible in this than in the
former analyfis.

(B) Nitrous acid was repeatedly abftracted
from the other 87 parts, even to ignition,
and afterwards whatever that menftruum
could take up was diffolved.

(C) The folution, on examination, only
yielded zinc, which when precipitated by
phlogifticated alkali yielded 218 lb. of fedi-
ment, and then by volatile alkali 3 parts of
clay.

(D) From the remaining 31 parts, which
refifted the nitrous acid, the vitriolic was ab-
ftracted to drynefs; upon which it was
elixated with diftilled water, and 24 only
remained.

(E) The folution of (D), precipitated by
phlogifticated alkali, yielded 29 parts of
Pruffian blue, which nearly correfpond to
45 of iron.

(F) The Pruffian blue being feparated by
filtration, the liquor had an aluminous
tafte;

tafte ; and this falt alfo appears upon cryf-
tallization, but mixed with vitriolated ve-
getable alkali.

(G) The 24 parts untouched by the acids,
were the reliquiæ of a quartofe matrix.

(H) Therefore 100 of this ore contains
about 17 of fulphur, 5 of water, 44 of zinc,
5 of iron, 5 of clay, and 24 of quartz.

It is probable that in this inftance the
zinc is more dephlogifticated than in the
others. Hence, from the unknown quantity
of the difference, an error arifes, perhaps of
fome pounds, which as yet cannot be de-
termined.

§ VIII. *Analyfis of the Pfeudo Galena of Boval,*
which poffeffes a metallic Splendor.

(A) 100 of the pfeudo galena of Boval,
loft by roafting 17, which by their fmell
feemed to be nothing but fulphur ; but
diftillation fhews that a fmall quantity of
water is alfo mixed with them.

The refiduum grows black on calcina-
tion.

(B) The 83 parts which remained were
wetted with three times their quantity of
concentrated vitriolic acid, and evaporated
to drynefs ; then all the faline part was fe-
parated from the white mafs, by boiling in
diftille d water, and 6 parts remained which
eluded the action of the menftruum ; which
were with difficulty taken up by microcof-
mic

mic falt, more readily by borax, but very
eafily, and with effervefcence, by mineral
alkali ; at the fame time the laft globules
were brown : hence it appears that they con-
fift of a filiceous and martial matter.

(c) In this inftance the colour of the fo-
lution does not betray copper, which yet is
fhewn by the microcofmic falt (§ 11.) ; but
the addition of iron foon removes all doubt.
In order to determine the quantity of this
metal, a polifhed plate of iron was boiled in
the folution as long as any of it conti-
nued to be taken up. The cupreous fedi-
ment, collected, wafhed and dried, weighed
4 lb. The plate was found to have loft 6 lb.

(d) In the remaining liquor phlogifticat-
ed alkali precipitates at once a white and a
blue fediment, which indicates the prefence
both of zinc and iron. In order to deter-
mine the proportions, this liquor, evapo-
rated to drynefs, was long calcined in the open
fire ; afterwards nitrous acid was repeatedly
abftracted to drynefs from the mafs, that the
iron, fpoiled of phlogifton, might be ren-
dered infoluble in that acid :—nor was the
experiment unfuccefsful, for the zinc alone
was taken up, and about 19 lb. of calcined
iron remained, which are equivalent to 14
parts of regulus, the weight being increafed
0,36 by calcination.

(e) The folution, containing zinc preci-
pitated by phlogifticated alkali, yields 259
parts of white fediment, wafhed and dried.

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(F) 100 of this ore, therefore, contains 52 of zinc, 8 of iron, 4 of copper, 26 of sulphur, and 4 of water, together with 6 of a siliceous and martial matter.

(G) That the metals exist either in a state nearly reguline or but little dephlogisticated, easily appears both by the metallic splendor, and the violence and redness of the vapours with which the nitrous acid attacks them; and, finally, by the union with sulphur. The same is nearly true of the ore of Dannemer, which, although destitute of metallic splendor, exhibits the same phænomena with nitrous acid (§ IX. c); and, besides, on sublimation, it exhibits a reguline arsenic (§ VI. B). But the pseudo galena of Sahlberg seems to contain a smaller portion of phlogiston.

(H) It follows, from the analysis of pseudo galena, 1. that lime, though it be sometimes present, is not necessarily required; for the three varieties I examined did not shew the slightest trace of it, even when the acid of sugar, its nicest test, was employed: it is certain, if the sulphur was here united with zinc in the state of an earthy hepar, that a small quantity of lime would not suffice, and part at least of the hepar might be elixated by water. 2. That the presence of cobalt and silver is accidental, as also of lead and arsenic in the Dannemer pseudo galena, and of copper in that of Boval. 3. That zinc, iron, and sulphur, are always present;

prefent; for zinc cannot be united with ful-
phur, but by means of iron. When thefe
three ingredients are fufed together, an ar-
tificial pfeudo galena is eafily made. But it
may be gathered from the water, that nature
has effected the union in the humid way.

§ IX. *The Phænomena of the hepatic Smell,
extricated by Acids from Pfeudo Galena.*

When the vitriolic or marine acid is
poured on pfeudo galena, an hepatic odour
is exhaled; but it may be gathered from
what goes before, that no alkaline falt nor
abforbent earth is prefent, and therefore no
hepar. Hence the caufe of this phæno-
menon may be properly enquired after.
—The following experiments will ferve to
folve the problem.

(A) Six affay 100 of black pfeudo galena
from Dannemer, well pounded, were put
into a glafs, and the bulb of the thermo-
meter was fet in the midft of it. 300 of
concentrated vitriolic acid being poured on,
a few bubbles arofe, and a diftinct hepatic
odour was perceived. In four minutes the
mercury arofe from 16 to 27; but in nine
it began to fink. The powder was fo much
indurated, that it was difficult to feparate
the thermometer without breaking it.

(B) The experiment was repeated with
200 of fmoking marine acid. A ftrong he-
patic odour, and a violent effervefcence, were

Z 2   obferved;

obferved; but the mercury in the thermo-
meter remained without motion.

(c) 200 of fmoking nitrous acid, di-
luted with an equal quantity of water, were
poured on the fame weight of ore, when an
intumefcence was perceived, and red va-
pours arofe, without any hepatic fmell. A
heat of 74° took place in four minutes.

The refiduum, after having been well
wafhed with hot water, produced no hepatic
fmell, either with the vitriolic or marine
acids.

(d) The hepatic vapour, extricated with
the affiftance of heat by vitriolic acid, out
of a quintal, and collected in quickfilver,
amounted to two cubic inches; but the
marine acid produced feven from the fame
quantity. The red fumes arifing when ni-
trous acid is employed were found on ex-
amination to be nothing but what is called
nitrous air.

(e) One-half of a quadrant of hepatic air,
collected in an inverted phial, and mixed
with an equal portion of nitrous air, be-
comes grumous, and depofits fulphur; and
the mercury in the thermometer fufpended
in it rofe to 6°.

(f) Yet all the pfeudo galenæ are not
equally affected by acids: if marine acids
be poured on the three above examined, that
of Dannemer emits an hepatic air, with
many bubbles; from that of Boval fewer
bubbles rife; and from that of Sahlberg,
<div align="right">fcarce</div>

fcarce any. The two firſt yield a very of-
fenſive ſmell, even though kept in corked
bottles for a number of years: the laſt has
but a faint ſmell, which continues only for
a few minutes: the others, boiled with acids,
fcarce extricate any hepatic odour.

(G) 2½ cwt. of yellow lapis calaminaris
from Hungary, treated in the ſame way as
the pſeudo galena, occaſioned with vitriolic
acid a degree of heat $= 65°$, but no hepatic
ſmell was perceived.

(H) The ſame ſtone generated heat with
nitrous and marine acid, but without any
hepatic ſmell.

(I) Flowers of zinc occaſion with acids
heat, but no ſmell.

§ x. *Explanation of the hepatic Odour.*

From the phænomena above mentioned
the origin of the hepatic odour is eaſily ſeen
both analytically and ſynthetically. We
ſhall firſt examine it *analytically.*

(A) That ſulphur enters the compoſition
cannot be doubted, as it is actually found
precipitated (§ IX. E.): but we are to en-
quire the cauſe which in this inſtance di-
lates the ſulphur which had been ſo ſubtilely
diſſolved into an aeriform elaſtic fluid.

(B) That heat exiſts fixed in hepatic air,
and is ſet at liberty by the deſtruction of that
air, evidently appears from the aſcent of the
mercury (§ IX. E.) The opinion that the
heat of bodies conſiſts in a certain inteſtine

Z 3 motion

motion of their parts, is at prefent held to be totally improbable. Many circumftances tend to prove, that heat is to be attributed to a matter diftinct from all others, which when difengaged occafions fenfible heat in proportion to its quantity; but fo long as it conftitutes a primary principle of bodies, its power of heating is repreffed (in the fame way as the properties of an acid faturated with alkaline falt) which power, however, it again recovers, when by any means fet at liberty; hence, in certain folutions, heat is generated; namely, when that principle which had been united with one of the ingredients is expelled by a ftronger attraction: in others cold is produced, occafioned by the heat entering into the new compound. Since, therefore, on precipitation of fulphur from hepatic air, heat is generated, we may conclude that the matter of heat had been before fixed. This conclufion will be further confirmed hereafter (E.)

(c) It appears plainly, that the phlogifton in hepatic air forms the bond of union between the matter of heat and the fulphur; for that air cannot be decompofed, except by fubftances which are extremely greedy of phlogifton: concentrated nitrous acid poffeffes this power, even in water loaded with hepatic air; nay, nitrous air, although fo much loaded with phlogifton that its acid properties are concealed, produces the

_ 7   fame

same effect (§ IX. E.) We see therefore, that upon the abstraction of phlogiston the whole composition is destroyed, so that it may justly be considered the bond of union. Sulphur, by means of heat alone, diffuses no hepatic smell.

All this is completely established by a right consideration of the principles of the pseudo galena, and its different habits with respect to acids. We now proceed to examine this subject *synthetically*.

The constituent parts of hepatic air being thus discovered by analysis, let us now examine synthetically whether these are to be found in the pseudo galena.

(D) Of sulphur we can have no doubt, as even the quantity of that has been already determined (§ VI.—VIII.)

(E) The presence of the matter of heat is equally certain, for the pseudo galena with nitrous acid excites a considerable degree of heat (§ IX. C.) ; and the vitriolic acid generates with it a degree of heat, though less. Thus we see the matter of heat more or less set at liberty.

(F) Besides the phlogiston of the sulphur, no small portion of that principle adheres to the metals, as has already been evinced (§ VII. G.)

All the principles therefore before discovered by analysis are present (A—C.)

(G) It may now be questioned, whether these principles are so united in the pseudo

Z 4   galena

galena as actually to constitute hepatic air, which, like the aerial acid in chalk, lies hid ; or whether it be on the addition of the proper acid that they first coalesce and form an elastic fluid.

(H) In order to determine this question, the pseudo galena was subjected by itself to distillation ; and the vapour extricated was collected in a pneumatic apparatus : but on examination nothing was obtained but a small portion of water, and nothing at all aerial : besides, all the different acids would expel the same quantity, if the hepatic air lay hid, like the fixed air in chalk ; but we have seen, that from 1 cwt. none was obtained by nitrous acid, two cubic inches by the vitriolic, and seven by marine acid (§ IX. D) ; the elastic fluid therefore does not pre-exist in a perfect state.

(I) It is generated therefore during the solution : for the addition of the acid, by loosening the texture of the mass, sets the heat at liberty, together with the phlogiston of the zinc and iron ; for no metal is taken up by acids, until it is dephlogisticated to a certain degree. The first effect therefore of acids upon metals is to deprive them of that portion of their phlogiston which prevents their solution, and by this privation they become soluble.

These two principles, heat and phlogiston, being set at liberty, seize the sulphur which they meet with, combine with it,
and

and form an elastic fluid; but as the nitrous
acid attracts and retains phlogiston with more
force than the rest, with it a great heat is
generated, but no hepatic air can be formed,
for the principle which should connect the
other two is wanting. The vitriolic acid
indeed attracts phlogiston less powerfully
than the nitrous, but does not yield up all
that it sets at liberty to the generation of
hepatic air; and this air is consequently
produced only in small quantity, indeed so
small that some heat remains at liberty:
but the marine acid, being naturally loaded
with phlogiston, does not attract any more;
therefore the whole of the heat may very
easily be fixed by the phlogiston extricated
by this acid from the metals; hence, with
this acid, there is no heat generated, but a
considerable quantity of hepatic air. The
calcined pseudo galena retains, indeed, the
matter of heat, but loses the phlogiston and
the sulphur in the fire; therefore no ves-
tiges of hepatic air can arise here, as with
the lapis calaminaris (§ IX. F, G.)

All these circumstances agree so perfectly,
that no doubt can remain of the truth of the
explanation; yet pseudo galena is not to be
considered as the only body in nature which
can produce an hepatic air and odour on the
addition of acids: it is enough to mention
galena, which occasionally exhibits the same
phænomena; for the marine acid acts most
efficaciously, but the nitrous shews not the
leaſt

least vestiges of any thing hepatic; and in this case the vitriolic acid has little effect, as it hardly attacks lead, when in a metallic state. It is also worthy of observation, that native Siberian iron, with marine acid, diffused a distinctly hepatic smell; but the examination of this would require a separate treatise.

§ XI. *Phosphoric Quality of the Pseudo Galena.*

Some varieties of pseudo galena upon friction shine in the dark; and among those the most remarkable is that which is found at Scharfenberg, in Misnia. This, when rubbed with glass, a bone, iron, or any hard substance, emits a fœtid smell; and at the point of contact sends forth a flame of a gold colour, and this happens in water, nay, even in acids, and it retains this property even after a violent white heat. Some insist that this light is electric; but the electric flash is of a very different kind, being entirely extinguished by water, whereas this is made rather more splendid. Latent light is not the cause, for in solution no light is occasioned.

Supposing that light be nothing but the matter of heat, with a determined superabundance of phlogiston, these principles are not deficient in the pseudo galena; for

we

we have already feen that the matter of heat is really prefent (§ x. B, E), and at the fame time phlogifton (§ x. c, F). The firft, there-fore, excited and fet at liberty by friction, may eafily feize the latter, and produce light.

Many varieties do not fhine at all, fome fcarcely, and a few very remarkably ; this is undoubtedly owing either to the propor-tion of the principles, or their clofenefs of connection ; which laft opinion is confirm-ed by obferving that thofe which poffefs the phofphoric quality in the moft eminent degree refift the three mineral acids, fo that either no hepatic odour or heat arifes, or at leaft much weaker than in the others, which indicates a firmer texture ; yet all that refift the acids are not found to be phofphoric. This difficulty is folved by the analyfis of the pfeudo galena of Scharfen-berg, the fcarcity of which has as yet prevented the experiment from being fuffi-ciently varied. The powder, expofed alone to fire in a clofe veffel, yields a filiceous fublimate, fimilar to that produced by mine-ral fluor and vitriolic acid. The fluor acid is therefore prefent, but probably united in fuch a manner to the metallic bafe, that it cannot, by fire alone, be expelled, and gene-rate with water a filiceous earth.

Marine acid by boiling diffolves it, when well powdered, almoft entirely, and produces an hepatic fmell ; for, exclufive of the ful-
phur,

phur, fcarce more than 0,01 remains, which, examined by the blow-pipe, appears to be filiceous. In 100 the zinc forms nearly 64, iron 5, fulphur 20, water 6, fluor acid 4, and filiceous earth 1 ;—nothing calcareous is found.

This pfeudo galena is lamellated, yellow, and femipellucid ; but, fituated in a certain way with refpect to the eye, it appears opake, fomewhat refembling a metal, like moft of the others. The various proportions feem to indicate, that in this inftance the metals are not prefent fully calcined. Fufed with microcofmic falt by the blow-pipe, it throws out a few flafhes almoft like that of Sahlberg, which was mentioned among the Swedifh pfeudo galenæ (§ 11.), a phænomenon which can hardly be produced with calcined zinc. With nitrous acid it produces certain vapours. It is indeed true, that it excites a very fmall detonation ; for the firft parcel thrown into nitre, well fufed, occafions nothing but an effervefcence ; and it is not until the fourth or fifth addition that fparks are produced, and even thefe are few. The Swedifh pfeudo galenæ, firft examined, detonate on the third or fourth addition : this difficulty of detonation rather points out the clofenefs of connection in the inflammable principle, than a deficiency of it ; for on the fame ground we might difpute the prefence of fulphur, which yet is moft certainly prefent.

DISSER-

DISSERTATION XXIII.

OF

METALLIC PRECIPITATES.

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§ 1. *Design of the Work.*

THE man who first saw a metal cor-
roded by a limpid menstruum, in such
a manner that a body so extremely ponde-
rous and so opake should gradually and en-
tirely disappear, and afterwards, upon the
addition of a suitable precipitant to a li-
quor which appeared to be simple and ho-
mogenous, saw that metal separate, and again
come into view ;—the man, I say, who first
saw this, must have been struck with
astonishment and admiration. Persons ac-
customed to these wonderful phænomena
<div align="right">neglect</div>

neglect perhaps too much the accurate in-
vestigation of them, though these operations
are of the highest importance, and form as
it were the whole of the effective part of
chemistry. The phænomena of this kind
are so various and so intricate, that a single
volume would be utterly insufficient for
examining them all: we shall here therefore
only examine such as relate to the separation
of metals from acids, particularly with re-
gard to the weight of the precipitate.
Weighing is, no doubt, a mechanical opera-
tion, but yet is of singular service not only
in investigating the properties of bodies,
but in directing those properties to their
proper uses. All effects are exactly pro-
portioned to their causes; therefore, unless
their mutual relations be examined by accu-
rate trials, theory (of consequence the whole
of natural philosophy) must be lame and
imperfect.

That we may the better understand the
nature of precipitations, we shall briefly
examine the phænomena of metallic solu-
tions in general.

§ II. *Examination of Metallic Solutions.*

A small piece of a metal being put into
an acid, is taken up slowly or quickly, with
violence, or gently, according to the various
nature of the metal and the menstruum.

(A) As

(A) As to menſtrua, when unaſſiſted by heat, the nitrous acid is found the moſt powerful, ſo much ſo as ſometimes to exceed the bounds required; and the metal diſſolved is again ſeparated, unleſs the violence of this acid be properly tempered: yet ſometimes the nitrous acid alone has no effect, as is the caſe with gold and platina; but when the nitrous is united with the marine acid, the ſolution is readily effected.

The vitriolic acid, though very highly concentrated, yet acts more weakly. It does not attack mercury or ſilver, unleſs when boiling; and gold and platina elude its force, even though boiled to dryneſs.

Marine acid acts ſtill more weakly, unleſs it be dephlogiſticated (a); in which ſtate it diſſolves all metals compleatly.

The other acids, as the fluor acid, the acids of arſenic and borax, and all thoſe obtained from the organized kingdom, are in general inferior in ſolvent virtue to the preceding.

(B) With reſpect to the metals, ſome are very eaſily diſſolved, others not without great difficulty, and that in the ſame menſtruum. Zinc and iron are readily diſſolved in every acid; ſilver eludes the marine, and gold even the nitrous acid. Yet theſe metals, which in their natural ſtate obſtinately

(a) Nov. Act. Upſal, vol. ii.

refift folution, may be made foluble by depriving them of a proper proportion of their inflammable principle. I exprefsly mention a proper proportion, for experience fhews, that iron, and particularly tin, are made refractory by too much dephlogiftication; but nothing more plainly fhews the limits of this procefs than manganefe, which when calcined to blacknefs cannot be diffolved without the addition of fome inflammable matter, but when reduced to whitenefs diffolves in all acids (b).

(c) If we confider the manner of the folution with accuracy, we fhall find that the diminution of complete metals, even to the laft vifible particle, is accompanied by an effervefcence; that is, innumerable air-bubbles continually rife from the furface of the metals, and float to the furface of the furrounding liquor. Thefe are the more frequent, in proportion to the quicknefs of the folution, and are very few, and fcarcely vifible, when it proceeds very flowly.

The elaftic fluid, which is thus extricated from metals by nitrous acid, if collected by a proper apparatus, and examined, is found to be nothing more than what is commonly called nitrous air; but when the menftruum is concentrated it abforbs a confiderable quantity of this air. By means

(b) See the Treatife on the white Ores of Iron.

2   of

of vitriolic acid inflammable air is obtained from zinc and iron, as alfo by means of marine acid; but from the other metals diffolved in vitriolic acid, we obtain another fpecies of air, called *vitriolic acid air*; and by the marine acid, another fimilar to the former, called *muriatic air*, but both more or lefs mixed with inflammable air.

(D) Frequently, during the folution of a metal, heat is generated in the liquor, the intenfity of which follows the compound ratio of the bulk of the mafs, and the quicknefs of folution; therefore, when the mafs is very fmall, and the folution proceeds very flowly, the temperature fcarcely fuffers any alteration.

(E) The calxes of metals, during folution, either give out no air at all, or elfe the aerial acid; unlefs when, after being evaporated to drynefs, they are urged by a violent heat almoft to ignition; for in this ftate, by means of vitriolic or nitrous acid, they give out a portion of pure air, which cannot be got by means of marine acid: according to circumftances, a vitriolic or nitrous air is alfo fometimes produced, and even that fpecies which is commonly called phlogifticated air.

(F) Various metals, when diffolved, impart certain determined colours to their menftrua; fuch are gold, platina, copper, iron, tin, nickel, and cobalt; the reft, if properly depurated, yield no tinge.   A fo-

lution of silver, at first, is sometimes of a
blue or green colour, although there be no
copper present. The vitriolic acid grows
blue with copper; the nitrous may be made
either blue or green at pleasure; the marine
varies according to the quantity of water
with which it is diluted; manganese, when
too much dephlogisticated, renders both the
vitriolic and marine acids purple.

§ III. *Explanation of the above-mentioned Phænomena.*

At present no one can reasonably doubt
that solution is the effect of attraction; we
may therefore lay that down as a funda-
mental proposition, and proceed to illustrate
(in the best way we are able) the more re-
markable circumstances of the operation,
considering it not in a general view, but
merely as it regards metals.

Upon attentive consideration it readily
appears, that " *no metal can be taken up by an*
" *acid, and at the same time preserve the whole*
" *quantity of phlogiston which was necessary*
" *to it in its metallic state.*" A certain pro-
portion therefore of the principle of inflam-
mability may be considered as an obstacle,
which must be removed before solution can
take place. Let us see now how this doc-
trine will apply to the more remarkable
phænomena separately considered.

(A) Of

(A) Of all the acids the nitrous attracts phlogiston the moft powerfully, and feparates even from the vitriolic acid. If this be doubted, let fulphur be flowly boiled in concentrated nitrous acid, at length all its phlogiston will be found feparated, and the vitriolic acid will remain deprived of its principle of inflammability. The extraordinary folvent power of this acid, therefore, is conformable to the peculiarity of its nature in this refpect; for this menftruum adapts metals for folution with the greateft eafe, moft commonly without any affiftance from external heat, which in fome inftances would be hurtful, by feparating too much of the phlogiston. This laft cafe is fufficiently illuftrated by iron, tin, and antimony, all which may be fo far deprived of phlogiston as to be very difficultly foluble in acids; it is therefore not unfrequently neceffary to temper the activity of this menftruum by water.

The vitriolic acid does not act upon filver or mercury, unlefs when boiling; for by means of the heat the watery part of the acid is diminithed, its power is thereby increafed, and the connection of the inflammable principle with the metallic earth is diminifhed.

Marine acid, which contains phlogiston as one of its proximate principles, muft neceffarily have but little or no effect on thofe metals which retain their principle of in-

A a 2   flammability

flammability very obftinately ; but when boiling, its watery part is diminifhed, and it affumes the form of an aerial elaftic fluid, in which ftate it powerfully attraĉts a larger proportion of phlogifton than before ; but when dephlogifticated, it attraĉts phlogifton with prodigious avidity, readily attacking all metals, and rendering them foluble by the abftraĉtion of their phlogifton, which it unites to itfelf, and refumes the ordinary form of marine acid. This acid, when dephlogifticated in aqua regis by means of the nitrous acid, diffolves gold and platina.

Upon this principle we can eafily account for the inferiority of power in the other acids.

(B) As to the metals, they retain their phlogifton with very unequal degrees of force: a few of them, which are called the perfeĉt metals, effeĉtually refift calcination in the via ficca. In this operation, on the one hand, the fire, which wonderfully encreafes the volatility of bodies, ftrenuoufly endeavours to expel the phlogifton, which certainly is the lighteft of all material fubftances ; on the other, the portion of pure air which occurs in the furrounding atmofphere attraĉts the phlogifton ftrongly : experience however fhews, that thefe two forces united cannot decompofe gold, platina, or filver, to any confiderable degree ; all the other metals yield to thefe forces when united, but not fingly. Iron and zinc retain their inflammable principle

ciple

ciple fo flightly, that any acid immediately acts upon them ; but if, by dry calcination, metals be properly prepared, the men-ftrua will immediately take them up ; nor is there need of any further privation, which, on the contrary, would be inju-rious, and precipitate what was before diffol-ved. For example, let us recollect the ef-fect of the nitrous acid : this, added to folu-tion of tin or antimony in marine acid, by its extraordinary violence carries off fo much phlogifton that the calxes, being too much deprived of that principle, are precipi-tated.

(c) We are now come to the moft diffi-cult point of all, I mean the production of the various elaftic fluids which refemble air. The complete difcuffion of this fub-ject does not properly belong to this place ; but, as fome circumftances, hereafter to be mentioned, cannot properly be underftood without a knowledge of the fundamental principles of this phænomenon, I think it neceffary to give a brief relation of what I have been able to learn on this head, from my own experiments and thofe of others ; fome of which I apprehend to be certain, and paft controverfy ; others (as yet only plaufible) to be confirmed, corrected, or re-jected by new experiments.

A great variety of different aeriform fluids have been obferved ; of thefe eight only are certainly known with refpect to their com-

pofition ;

pofition; thefe are the fluids extricated by the vitriolic, nitrous, and marine acids, fluor acid, vinegar, alkaline falts, and hepar fulphuris.

Pure vitriolic acid, expofed to a violent heat, is indeed refolved into vapours, but vapours of fuch a nature, that when the heat is gone they condenfe again into an acid liquor of the fame nature as before; but if any fubftance be added which is loaded with phlogifton in a feparable ftate, by means of fire an elaftic vapour is produced, which is not condenfable by the moft extreme cold, provided it does not come in contact with water. This is the *vitriolic acid air*, which may be totally abforbed by water; in which cafe the bond of union between it and the phlogifton is fo weakened that this laft gradually flies off, and at length common vitriolic acid is regenerated. We fee, therefore, that this acid, by means of a fufficient quantity of phlogifton, may be expanded into an elaftic fluid.

The nitrous acid undergoes a fimilar and more perfect change in a manner ftill more obvious:—let a fmall piece of filver (for example) be put into nitrous acid, and inftantly innumerable bubbles arife, and float to the furface; thefe collected produce the *nitrous air*. The bubbles upon the furface of the metal, where the acid particles are fufficiently loaded with phlogifton, affume an elaftic and highly dilated form; fo
that

that they rife by their fpecific levity, and chace one another from the feveral points of the metal. The nitrous acid faturates itfelf with phlogifton more greedily than the vitriolic ; and therefore the elaftic fluid does not unite with water, and retains fcarcely any veftige of an acid nature. Synthetical obfervations agree perfectly with analyfis ; for upon the accefs of pure air, which poffeffes a ftill greater attraction for phlogifton, the acid yielding it up immediately reaffumes its original form and properties ; but the nitrous air differs fomewhat from the vitriolic alfo in this refpect, that the phlogifton is not only abforbed fo far as to obliterate the acid nature, but even beyond that point. This I am convinced of by many experiments, one of which will be fufficient, namely, the decompofition (*c*) of hepatic air by means of nitrous air.

The marine acid exhibits different phænomena : this acid contains phlogifton, and by its means can be refolved into an elaftic fluid called *muriatic air*, which is permanent fo long as it is kept from the contact of water ; but, like the vitriolic, upon the accefs of water it reaffumes the form of marine acid. As this acid naturally contains phlogifton, there is no neceffity for an addition : in the mean time this, in the fame manner as nitrous air, when in its ex-

(*c*) See Treatife on the Ores of Zinc, § IX. E.

A a 4   panded

panded state, attracts a still larger proportion of phlogiston, and that with wonderful avidity.

When the natural quantity of phlogiston is diminished the marine acid yields another elastic fluid of a reddish brown colour, possessing the peculiar odour of warm aqua regia. This does not unite with water, or but in an exceeding small quantity; and, upon the addition of a due quantity of phlogiston, may be again reduced to marine acid. The experiments made on the black calx of manganese and on white arsenic (d), which I have often repeated and carefully weighed, I consider as indubitable evidences of this connection. Whether the marine acid can by any other than these two methods be dephlogisticated, I am as yet ignorant.

The fluor acid abounds with phlogiston, and therefore may, without any adventitious matter, be reduced to an elastic fluid. This air is easily distinguished from all others, as when hot it corrodes glass.

Vinegar also naturally contains phlogiston; and for that reason, when well dephlegmated, can produce an elastic vapour, which is called *acetous air*.

All these elastic fluids seem to be nothing more than the acids themselves, expanded by phlogiston. Perhaps the matter of heat also enters into their composition.

(d) Nov. Act. Upsal, vol. ii.

This

This is alfo the cafe with cauftic volatile alkali, which yields the *alkaline air*.

Finally, among thofe elaftic fluids, the compofition of which we are acquainted with, we may place the *hepatic air*, in which we have demonftrated fulphur (e) united with the matter of heat, by the intervention of phlogifton.

The origin of the other elaftic fluids is as yet fo involved in darknefs, that we can fcarcely eftablifh any thing certain with regard to them : thefe are of four kinds ; and, in conformity with the received opinion concerning their properties, are called *fixed air*, *phlogifticated air*, *dephlogifticated air*, and *inflammable air*.

Of the firft I think it is evidently demonftrated to be of a peculiar nature, and always acid. Dr. Prieftley confiders it only as a modification of nitrous acid ; nay, he urges that the vitriolic and nitrous acids are no more than varieties of the fame fubftance. This point I will not abfolutely deny ; but the foundation on which thefe affertions reft feems to me to be very infufficient. Thus, in the preparation of ether by vitriolic or nitrous acid, he obtained a confiderable quantity of fixed air, which he affirms to have been generated during the operation ; but we muft obferve, that a large proportion of fpirit of wine enters into this

(e) Treatife on the Ores of Zinc, § ix. x.

preparation.

preparation. Now we find that fixed air abounds almoft every where throughout all organized bodies; why then fhould fpirit of wine, which owes its origin to vegetables, be fuppofed entirely void of it? As this is very volatile, it is only in a clofe veffel that it remains entire, and eludes the force of fire; but when hot, it gives off the fixed air: befides, by the addition of the ftronger acid, its texture is broken, and the fubtile acid, which before was latent, now breaks forth. Add to this, that, whether vitriolic, nitrous, or marine acid, or even vinegar, be ufed in the preparation of ether, aerial acid is produced: either then the aerial acid is common to all the acids (which is by no means confirmed) or it is derived from the decompofition of the fpirit of wine; otherwife I acknowledge, that the conjecture of fixed air originating from nitrous acid, does not appear improbable; of which we fhall fay more hereafter.

That fpecies of air, which is indifpenfably neceffary for the fupport of flame, and for animal refpiration, is generally called *dephlogifticated*. This air, united with a certain quantity of phlogifton, conftitutes the matter of heat, as Mr. Scheele has demonftrated by a long train of experiments, the chief of which I have repeated with the fame fuccefs. Setting this down as a principle, let us fee what alterations fuch air is liable to. The pureft air of this kind which

5

can

can be got, cannot be rendered unfit for the fupport of inflammation or refpiration, either by flame, by nitrous air, by electrical fparks, or any other of thofe operations by which we certainly know phlogifton to be fet at liberty; yet it contracts in dimenfion, and is at length entirely confumed, and that in fuch a manner that, united with the phlogifton, it forms the matter of heat, and, being utterly incoercible, pervades all manner of veffels. A very elegant appearance may be produced by this air; for if a piece of wood, or a candle newly extinguifhed, be put into a bottle containing it, provided the fmalleft particle remains ignited, a flame is inftantly kindled with a bright corufcation, and as it were explofion: this flame is diffufe and decrepitates, and the eye can fcarcely bear its fplendor. When this experiment is performed in an inverted veffel, the orifice of which is kept beneath mercury, it is evidently feen that almoft the whole of the air difappears; the remainder amounts to $\frac{1}{6}$, $\frac{1}{16}$, nay fometimes fcarcely forms $0,01$ of the original bulk; and this refiduum confifts partly of aerial acid, and partly of air unfit for fuftaining flame, or being fubfervient to refpiration, which had been originally mixed with the pure air.

The fame thing takes place on the admixture of dephlogifticated and nitrous air;

fometimes

fometimes fcarcely any remains, fometimes $\frac{1}{10}$ of the bulk, but in general much more. The variations in the quantity of the refiduum are fufficient to fhew the different degrees of dephlogiftication, or (which is the fame) the different degrees of purity of the air. This purity may be accounted for in three different ways : for either all its particles may be of the fame nature with the whole; or a certain number of exceeding pure particles may be mixed with a determined quantity of fuch as are very impure ; or, finally, the different particles, being each endowed with their own peculiar degree of goodnefs, compofe a mafs of an intermediate nature. Each of thefe cafes may occafionally take place ; but in my apprehenfion the laft feems to be more conformable to the ufual order of nature. With refpect to the explanation of the phænomena, they all apply equally ; but as the fecond appears to be the moft fimple, I chufe that. Let us now fuppofe the perfect nitrous air (which, upon the lofs of phlogifton, is all refolved into nitrous acid) mixed to the point of faturation with dephlogifticated air, then all the elaftic fluid, which had been confined by the glafs, difappears, by generating heat and penetrating the veffel. This takes place if the dephlogifticated air be perfectly pure ; if not, the refiduum will determine the degree of its impurity. Upon

3   this

this principle the beſt common aerial air is ſaid to contain of dephlogiſticated air $\frac{3}{4}$, and the worſt $\frac{1}{4}$.

It is probable that good may be converted into noxious air; this muſt be owing either to the abſtraction of ſomething from the maſs, or the addition of ſome heterogeneous matter to it. The ableſt philoſophers have, by unanimous conſent, determined the latter to be the caſe, and conſider phlogiſton as the cauſe of this corruption.—However, let us for a minute wave theſe opinions, how reſpectable ſoever, and candidly enquire into the truth of the fact, at the ſame time begging pardon for the boldneſs of our attempt.

Let us examine thoſe proceſſes by which phlogiſtication is performed: let us ſuppoſe a lighted candle ſet cautiouſly in air of abſolute goodneſs; we ſhall ſee an exceeding vivid flame, and the candle will be conſumed with extraordinary ſwiftneſs, until a ſmall portion of air remains, which exhibits the properties of aerial acid, proceeding doubtleſs from the tallow, into the compoſition of which that acid enters in great quantity. The phlogiſton, being ſet at liberty by the combuſtion, is ſeized by the pure air, is converted into heat, and penetrates the veſſels; and hence the diminution of bulk which is obſerved. If at firſt there had been more or leſs of air unfit for ſuſtaining flame, that air will be in the end

left

left behind entirely unchanged, together with the aerial acid; but in this cafe the diminution of bulk will be lefs.

We have already explained the mode of operation of the nitrous air.

Let a mixture of tin, lead, and bifmuth, which melts by the heat of boiling water, be fufed in a clofe glafs veffel, the air which is included will be diminifhed in proportion to its goodnefs; and if this be abfolutely pure, a proportional quantity of the metal will be entirely calcined, and the whole of the elaftic fluid will difappear.

Electrical fparks are fmall flames, which indicate the extrication of phlogifton, and at the fame time generate heat.

All thefe phænomena concur in fhewing that pure air acquires, by phlogiftication, fo great a degree of fubtlety, that it cannot be confined in glafs veffels, nor be any longer infpired; but no noxious air is produced. Now, if a fimilar phlogiftication took place on refpiration, a fimilar diminution of bulk would alfo be obferved, which is contrary to experiments the moft accurate. Mice, when included in air confined by mercury, and fuffered to die there, do not occafion, in general, a diminution of air equal to $\frac{1}{150}$, a lofs which is doubtlefs owing to the fmall portion of air expelled by the heat of the animal at its firft introduction. A very different operation feems therefore to be performed in the procefs of refpiration, from

that

that which is carried on during deflagra-
tion; perhaps the air rather conveys phlo-
gifton to the lungs than takes it away. From
whence does a pine, growing in the dryeft
fand, receive its oily matter, is it not from
the air? Such animals as by manducation
mix a large quantity of air with their food,
are obferved to grow fat in an extraordinary
degree. But we fhall wave thofe arguments
drawn from analogy, and proceed to fuch as
are more direct :—the air in which flame is
extinguifhed, can be breathed almoft as long
as aerial air; neverthelefs, during deflagra-
tion, phlogifton is copioufly evolved, and
by it the pure air is fitted for efcaping
through the veffels, but is not vitiated,
which it always is by refpiration. Frefh
blood, when agitated in pure air, does not
diminifh its bulk, but renders it unfit for
fupporting flame. But if the difcharge of
phlogifton from the lungs was fo indifpen-
fably neceffary as the moderns affert, un-
doubtedly inflammable air would be the
moft noxious of all; neverthelefs, the ce-
lebrated Mr. Scheele had courage to make
the experiment, and to infpire air, extri-
cated from iron by vitriolic acid, no lefs
than 30 fucceffive times. After this, its
bulk was found the fame as before; and its
inflammability not only deftroyed, but its
nature fo changed that it extinguifhed flame.
I have myfelf repeated this remarkable ex-
periment

periment with the fame fuccefs, except that I was not able to infpire above 20 times.

Hence it appears at leaft, that phlogifton may be abforbed by the lungs, without any confiderable danger. I acknowledge, that fmall animals, when inclofed in this kind of air, foon perifh ; but this does not, in my judgment, at all tend to fhew, that the inflammable principle, in more fimple combinations, cannot be innocent, or even falutary and neceffary, to the animal œconomy. When we confider the prodigious quantity of this fubtile principle, which is found in all organized bodies, the powerful effects which the proportion of its quantity produces in the formation of different fubftances, we fhall foon fee the neceffity of continually repairing the lofs of phlogifton which the blood fuffers during circulation from the feveral fecretions. Let the fagacious obfervers of nature examine carefully this problem ; let them devife and execute fuitable experiments, and I truft that this material point will foon be determined. In the mean time, fince all organized bodies are incapable of flourifhing, or even of exifting, without good air, we muft take leave to call this air *good*, or rather *pure*, until its dephlogifticated ftate is evinced by uncontrovertible arguments ; and to call that air *vitiated* which is ufually called *phlogifticated*, as it labours perhaps rather
under

under a deficiency than a fuperabundance of phlogifton.

I fhall here briefly explain a theory of aeriform fubftances, fome circumftances of which I hinted in an oration before the Royal Academy of Sciences, in 1777. Some of thefe circumftances have fince appeared to me eftablifhed beyond doubt, and others of them only probable, but yet to be fuch as agreed well together, and are at leaft worthy of a more accurate examination. Whether the confequence of this examination be to eftablifh or to overthrow them, natural philofophy will be enriched, and I will not fpare them myfelf, if by new experiments I fhall difcover them to be falfe. In the mean time I hope that a curfory account of them will give occafion to decifive experiments.

The celebrated Dr. Prieftley has fhewn, by a multitude of experiments, that dephlogifticated air may be extricated from almoft all bodies, by means of nitrous acid. He has alfo fhewn, that this air is found occafionally more or lefs mixed, fometimes with aerial acid, fometimes with nitrous air, fometimes with that elaftic fluid which is called phlogifticated air, fometimes with all of them together, yet fo difpofed that they generally exhibit themfelves in various order ; fo that from the fame mixture, expofed to fire in different veffels, fometimes one of thefe fluids will appear firft, fometimes in-

termediate, and fometimes laft. He has
fhewn that nitrous acid is very greedy of
phlogifton; and that it is wonderfully di-
verfified by the variety of quantity and con-
nection of this principle. I fuppofe it is
well known that a large proportion of phlo-
gifton in a body renders it in general im-
mifcible with water, &c.

*May not therefore the nitrous acid, by a
certain quantity of phlogifton, be converted in-
to aerial acid*—the phlogifton imparting to
it elafticity and levity, weakening its acidi-
ty, increafing its attraction for abforbent
earths, and changing its former properties,
or creating new?

*May not its acidity be fo far reprefsed by a
ftill greater quantity of phlogifton*, that it will
elude our examination, refufe to unite with
water, be neither eafily deprived of its phlo-
gifton, nor any further loaded with it;
being unfit for refpiration by its obftinate
retention of phlogifton, and for the fuftain-
ing of flame by its being no longer able to
take up more—thus generating that fpecies
of air which is called phlogifticated?

*May it not, by an abundant quantity of
phlogifton, be perfectly mitigated, and fo become
ufeful both to flame and refpiration?* Thence
on the one hand, by any further increafe of
the inflammable principle, it becomes fo
fubtilized as to generate heat, and thus fuf-
tains fire and flame, in which ftate it per-
vades all veffels; and on the other hand, by
any

any further diminution of that principle, or (if we may ufe the expreffion) a deter-minate calcination, returning occafionally to the ftate of phlogifticated air or aerial aid. Animals provided with lungs are lefs able to dephlogifticate this air than thofe which breathe through fpiracula, or than vegetables; the former converting it into phlogifticated air, the latter (f) into aerial acid. The experiments which have hither-to been inftituted in another way fhew a very different effect of vegetation upon air; but if I am not miftaken the caufe of the difference depends upon the diverfity of cir-cumftances. We know that vegetables lan-guifh, grow tranfparent, and lofe their co-lour in the dark; but when thus vitiated are fpeedily reftored by the rays of the fun. Light confifts of the matter of heat, with an excefs of phlogifton; this excefs is firft ab-forbed, and afterwards by degrees, though with more difficulty, the phlogifton itfelf, which conftitutes the matter of heat, is fe-parated; for no vegetation can proceed without heat: and by this procefs the other principle, the pure air, is fet at liberty. Therefore, according to the inequality in the degrees of heat, according to the different pofition of the vegetables with refpect to light, according to their different power in

_____

(f) Mr. Scheele found that good air was gradually converted into aerial acid by infects or vegetables in-cluded in it.

decompofing

decomposing light and heat, diffimilar effects muft necessarily take place.—Even water itself, which appears fo fimple and homogeneous a fubftance, frequently contains invifible organized bodies, which, when operated upon by the fun's light, by their vegetation produce the fame decompofition, and generate pure air.

If the varieties of noxious air can be rendered wholefome by agitation in water (which I confefs I have not yet examined with due accuracy) according to our hypothefis all the varieties, except inflammable air, fhould be loaded with phlogifton during the operation. It is known that water always contains a portion of pure air (g); and daily experience fhews, that air difperfed through water may, by continued agitation, be again collected, efpecially with the help of a little heat. Do not the emendations of air depend upon this? Water deprived by boiling of its air, fpontaneoufly recovers it when expofed to the open air: but water is not fluid without the affiftance of heat, and to that end it requires a degree equal to $72°$ (h). I can fcarcely believe that the matter of heat undergoes any decompofition during the agitation; but if that fhould fo happen, an air being prefent which wants phlogifton, a double fource of pure air will occur; the one by its fuperabundant phlo-

(g) Vol. i. p. 111.   (h) Vol. i. p. 286.

gifton

gifton correcting the noxious air, the other, by the extrication of phlogifton, fetting free the pure air which had before entered into the compofition of the matter of heat.

But it is not yet fufficiently clear what rank in this order is to be affigned to the *nitrous* air : it abounds with a larger quantity of phlogifton perhaps than the aerial acid, but more weakly united, on account of the moifture which the celebrated Fontana has fhewn to enter its compofition. Here too we are at a lofs for the reafon why pure air, already loaded with phlogifton, is yet able to defpoil the nitrous acid of that principle.

Inflammable air is undoubtedly charged with abundance of the principle of inflammability ; but in other refpects its compofition is very obfcure. On the one hand it cannot exift in a perfect ftate in bodies before its feparation, as, if that was the cafe, it could be extricated even by nitrous acid ; nor on the other, does it feem to require the admixture of any particular acid ; for it is extricated from iron equally by the vitriolic and the marine, and even by any acid, except that of arfenic, and, what is moft of all to the purpofe, without the affiftance of any acid menftruum whatever, but merely by a proper degree of heat. It is reduced by refpiration to a vitiated air. If therefore the above theory be agreeable to truth, the principle of it ought to be found in the nitrous

B b 3   acid ;

acid ; but as pure air, on the accefs of a greater quantity of phlogifton, conftitutes the matter of heat ; and that which is called inflammable air feems to exceed the pure in quantity of phlogifton, yet does not thereby acquire fubtlety enough to penetrate glafs ; there exifts perhaps in this cafe fome peculiar connection : for we cannot eafily conceive that the bare increafe of phlogifton can render the texture of its parts too grofs to pafs the pores of the glafs : we muft however confefs that fulphur, which is perhaps more loaded with phlogifton, is much denfer than vitriolic acid. Yet, although inflammable air diffolves fomewhat of the metal, carries it up, and after depofits it in water, we cannot properly conclude that the metal is neceffary to its compofition : in like manner other heterogeneous matters may be mixed by folution with the other aeriform fluids, and afterwards removed without injuring the properties of the fluids.

Nature proceeds by infenfible gradations ; but it is not in our power to follow her clofely, being only capable of diftinguifhing the more remarkable fteps. There is no doubt but other elaftic fluids form intermedia between thofe that we are acquainted with ; of this we are the more confident, as we know for certain that pure air, nitrous air, and inflammable air, are not always procured of the fame degree of virtue and efficacy.

If.

If this theory, gathered from such phæ-
nomena as are at prefent known, be true,
it will not be difficult to underftand the ge-
neration of nitre upon the furface of the
earth ; the inimical nature of aerial acid,
with regard to refpiration, above all other
noxious fluids, a property by which it is
capable, when taken into the lungs, of de-
ftroying as it were the original ftamina of
the animal machine ; and many other cir-
cumftances hitherto involved in impenetra-
ble darknefs.

(D) As to the heat generated during the
folution of metals, it is owing to the matter
of heat which had been fixed in the metals,
and is now fet at liberty by the acid men-
ftrua. All metals are eliquated by fire, fo
that we cannot determine whether this de-
pends upon the fire ufed in fufion, or whe-
ther it belongs to metals themfelves. Many
bodies retain a confiderable quantity of heat
fixed, although they have never been ex-
pofed to the fire, as we have already fhewn
in the inftance of lapis calaminaris (i).

(E) The calxes of metals are deficient in
that quantity of phlogifton which is necef-
fary to their metallic ftate, but yet are not en-
tirely without it ; therefore in their folution
fcarce any elaftic fluids are generated, unlefs
the fire be continued after exficcation ; fuch
as contain aerial acid difcharge it imme-

(i) Treatife on the Ores of Zinc, § ix. H.

B b 4   diately

diately in the fame form as they had received it. It is remarkable, that Dr. Prieftley mentions a calx of lead which, with the acid of phofphorus, produced an inflammable air. By means of the nitrous acid, and evaporation to drynefs, a pure air is produced, partly by the decompofition of the matter of heat, and partly by the phlogiftication of the nitrous air; for metallic calxes, and feveral other earthy matters, attract the nitrous acid, and fix it to a certain degree, fo that it can be loaded with the phlogifton of the heat; during which operation the pure air, which is the other principle of heat, is fet at liberty, and at length a like air is generated from the nitrous air. Pure nitre, urged by fire, illuftrates this procefs very well. If nitre be kept red hot upon a tile for half an hour, and upon cooling vinegar be added, or even a weaker acid, immediately the phlogifticated nitrous acid is difcovered by its fmell; but from whence can this phlogiftication be deduced, only from the heat paffing through? Befides, by a long continued fire, all the acid is expelled; but a very fmall quantity of it may be collected in a recipient adapted for the purpofe; and in the mean time, by means of a pneumatic apparatus, air of different degrees of goodnefs may be had in great plenty.—Does not this manifeftly indicate fucceffive changes taking place in the acid?

Some-

Sometimes a fmall portion of vitriolic air is had, by means of a proper degree of fire, from vitriolic acid, but a far greater quantity of pure air, occafioned by the decompofition of the heat.

(F) The folution made by the menftrua above mentioned contains a metallic calx intimately united with the acid ; but the quantity of phlogifton remaining varies, according to the difference of the menftrua, and of the temperature. The operation being performed, either with or without an intenfe heat, frequently occafions a notable difference, as we have already obferved in the inftance of (k) nitrated mercury. That calcination is effected more gently by the marine than by the nitrous acid, will eafily appear on pouring concentrated nitrous acid on tin or antimony ; the difference is not fo vifible in the other metals, if it actually does take place.

As the neceffity of this calcination, during the folution of metals, has been thought by fome modern chemifts not only doubtful but even falfe, let us here confider feparately, but briefly, the cafe of the perfect metals, which they infift ought to be excepted, as they do not yield to the moft intenfe fire. Let us therefore obferve, 1ft, that during their folution nitrous air is always generated, and of a very perfect kind ; this

(k) Vol. i. p. 132.

cannot

cannot arife without phlogifton, but in this cafe there is nothing prefent which can yield phlogifton, except the metals : therefore, 2d, the metals, when precipitated from the menftrua by fixed alkalis, both with refpect to their external appearance and internal properties, appear to be calcined ; *v. g.* the precipitate of gold rejects mercury, is diffolved in marine acid, and other fimple menftrua, and that without the production of any elaftic fluid. 3d, Glafs may be ftained by thefe metals ; but no metal in its complete form can be taken up by glafs, much lefs ferve to ftain it.

The vulgar objection arifes from hence, that the calxes of the perfect metals may be reduced folely by means of a fufficient degree of fire, without the addition of charcoal ; but this depends upon the great force with which thefe calxes attract phlogifton, fo that they are able to decompofe the matter of heat, and to take away and retain as much of that principle as is fufficient to give them the metallic form ; and it is for this reafon that they refift the effect of fire fo obftinately, when in their metallic ftate ; for when any phlogifton is taken away, it is inftantly replaced. The calxes even of the imperfect metals attack phlogifton, but are not able to retain a fufficient quantity. Mercury is a fort of intermediate fubftance, as it may, like the imperfect metals, be calcined by fire alone, though with much difficulty,

ficulty, and yet, like the perfect, it can from heat alone receive phlogiston to saturation.

The following has been proposed to me as an inextricable dilemma : " Silver cannot
" amalgamate with mercury, except when in
" its metallic state, yet both salited and ni-
" trated silver are taken up by mercury ; it
" is therefore not calcined by the acids, but
" adheres to them in its metallic form." We shall not need any assistance from the higher chemistry, in order to solve this. It is well known that the calx of copper, dissolved in vitriolic acid, is precipitated in its metallic form on the addition of iron, and that by means of a double elective attraction ; for the iron dissolving in the acid would form an inflammable air by its phlogiston, were not the copper present, which takes it up, and thereby becomes insoluble so long as it retains it : but from the table of elective attractions it appears that mercury possesses a stronger attraction for acids than silver does ; if therefore salited or nitrated silver be triturated with mercury, the silver must be precipitated in a metallic, and the mercury calcined be dissolved. This also takes place, provided there be moisture sufficient to suffer the elective attractions to operate ; the superabundant mercury greedily takes up the comminuted silver precipitate, and the arbores Dianæ are nothing more than such an amalgam crystallized. Upon this
head

head we shall say more (§ IV.) ; the fundamental objection is therefore, I hope, removed. But although the acids cannot take up any metal, while it retains its full proportion of phlogiston, yet various metallic salts are able to effect that solution ; thus nitrated or salited mercury boiled in water, together with the crude metal, can take up a certain proportion of it, without dephlogistication ; and the latter of these two salts by this method, even in the via sicca, becomes a mercurius dulcis, which contains at the same time a crude and a (*l*) calcined mercury.

Perfect solutions should in general be transparent, and some are also distinguished by a peculiar colour, namely, that colour which is proper to the calx, only rendered more vivid by the moisture. Thus solutions of gold and platina are yellow, those of copper blue or green, those of nickel of a bright green, those of cobalt are red, although the calx is black ; we may observe that even this red colour may be heightened to blackness ; iron, moderately calcined, is green, but this rarely continues upon further dephlogistication. The white calxes of silver, lead, tin, bismuth, arsenic, zinc, antimony, and manganese, are dissolved without colour ; but solutions of the lead, tin, and antimony, are somewhat yellow, unless suffi-

(*l*) Acta Stockholm, 1778.

5   ciently

ciently diluted. To this rule mercury forms a singular exception, for the orange-coloured calx of this metal is taken up by menstrua without colour.

That phlogiston is the chief cause of colour, appears also from hence, the black calx of manganese tinges vitriolic acid with a red colour, but on the addition of sugar the tinge is entirely (m) destroyed. Nitrous acid is rendered blue by copper, but when the metal is added in considerable quantity, it becomes of a very deep green; the marine acid, which dephlogisticates the copper less, is yet made green, but by dephlegmation may be so condensed as to appear brown. I have sometimes seen a solution of silver green, although there was not present the smallest particle of copper. This depends upon the absorption of nitrous air; for let smoking nitrous acid be diluted, on the addition of a certain quantity of water it will be of a deep green, by a greater blue, and upon a still greater, becomes limpid; by means of the water the nitrous air is extended to a greater space, and this attenuation, gradually increased, varies the colours. From what has been said it readily appears, why nitrous acid is made green by a large quantity of copper.

Metals dephlogisticated by acid solvents powerfully attract phlogiston; nay, nitrated

(m) Of the white Ores of Iron, § VII.

silver

filver and mercury, and falited antimony, corrode animal fubftances, in order to extract it. This metallic caufticity, which is only to be moderated by phlogifton, ought to be carefully diftinguifhed from the acid caufticity, which is repreffed by alkalis, and the alkaline, which is mitigated by acids. According to the quantity of phlogifton prefent, colours vary; and fome experiments fhew, that by a fufficient quantity all colour is entirely deftroyed, fomewhat in the fame way as a white light is generated by the union of the feven primitive colours —but of this hereafter.

§ IV. *Different Species of Precipitations.*

Various are the methods by which diffolved metals may be feparated from their menftrua; and the appearance and nature of thofe precipitates are occafionally varied in this operation in a very fingular manner. — We fhall mention fome of the moft remarkable.

(A) All metals may be precipitated by alkaline falts, which by their fuperior power of attraction feparate them from their menftrua; but the differences of thefe alkalis, with refpect to their nature and preparation, impreffes the precipitate with different characters.

With

With the cauftic fixed alkali the calxes fall almoft entirely pure, but loaded with water, and the matter of heat which is expelled from the alkalis by the acid. The weight is found to be encreafed by the water, and perhaps by the matter of heat; but yet lefs than by the aerial acid.

With the aerated fixed alkali, by means of a double decompofition, the aerial acid unites to moft calxes. We have already obferved, that the vegetable alkali, completely aerated, precipitates a white calx from falited mercury, but that the mineral alkali does not poffefs that (n) property.

The volatile alkali, which naturally contains phlogifton, fometimes phlogifticates the precipitates : it throws down a black or white precipitate of mercury; nay, makes the orange-coloured calx white, the reafon of which phenomenon we fhall foon (o) fee. Gold receives from this precipitant its fulminating quality, as before (p) explained.

The alkali, which is commonly called phlogifticated, generally precipitates metals with an increafe of weight, as Mr. Macquer firft demonftrated.

(B) Frequently the acids occafion precipitates, and that for different reafons.

By means of elective attraction, filver, mercury, and lead, are taken from the ni-

(n) Vol. i. p. 70.   (o) Vol. i. p. 132.
(p) Of the fulminating Calx of Gold.

trous acid, by the addition of the marine or
vitriolic. These acids form with the metals
new compounds, which are difficult of fo-
lution in water, they are therefore precipi-
tated in greater or lesser quantity, according
to circumstances.

By too much dephlogistication the nitrous
acid can decompound salited tin and anti-
mony: for when these calxes are too much
calcined they reject menstrua.

(c) Alkalis, saturated with acids, which
are called neutral salts, sometimes disturb
metallic solutions.

By means of a double elective attraction
all those which contain vitriolic or marine
acid decompose solutions of silver, mercury,
or lead, in marine acid, and precipitate the
metals.

By forming a triple combination, the ve-
getable, as well as volatile alkali, although
saturated with vitriolic, nitrous, or marine
acid, precipitate platina from aqua regia. If
the mineral alkali forms the base, the neutral
salt has no power of this sort; — these
phænomena are more accurately considered
elsewhere.

(D) Some metallic salts can decompose
others, and precipitate their bases. This
may happen when the acid is different in
the two salts, or, what is more singular, even
though it be the same.

Solution of gold gives us an example of
each

each of thefe two cafes (*q*). This, as is well
known, is precipitated by martial vitriol, al-
though the reafon, fo far as I know, has not
been yet explained; but upon examining
the precipitate carefully it will be eafily un-
derftood: for this, when wafhed and dried,
not only fhews many refplendent gold-co-
loured particles, but alfo unites with mer-
cury by trituration, diffolves in aqua regia,
but not in marine acid alone, together with
other circumftances which evince a com-
plete refufcitation of the gold. Cryftalliz-
able martial vitriol contains phlogifton, but
very loofely adhering (*r*), fo that the calx of
the gold may very eafily take it away to fup-
ply the lofs it had fuftained during the fo-
lution. That this is the true foundation of
the procefs, appears alfo from this, that the
weight of the diffolved gold is precifely re-
covered: it is alfo proved from this cir-
cumftance, that dephlogifticated vitriol will
not precipitate gold. It may reafonably be
enquired why the furrounding aqua regia
leaves fuch a precipitate untouched. The
reafon is, that the menftruum is diluted and
weakened by the quantity of water; for upon
boiling it gently, fo as to expel the water,
the menftruum recovers its folvent power,
and takes up the precipitate.—We come
now to the origin of the purple precipitate.

(*q*) Treatife on Platina.
(*r*) Vol. I. p. 137, 387, 392.

That a folution of gold in aqua regia
fhould be precipitated by a folution of tin,
the fame menftruum, is of more difficult ex-
planation : — in this cafe, it is the fame
menftruum that holds the two metals dif-
folved; what then is the caufe of the
change? At firft I imagined that the tin
had attracted a fuperabundance of the acid,
and taken it from the gold, which being
therefore deftitute of the proper quantity
muft neceffarily fall to the bottom : but
upon employing a folution containing fu-
perabundant aqua regia, the fame precipi-
tate was occafioned.   The caufe is therefore
not to be fought in the menftruum : let us
examine the precipitate itfelf, and perhaps
the knowledge of its properties will un-
fold the myftery.   Its external appear-
ance fhews nothing like the metallic fplen-
dor, but altogether refembles a calx : it is
eafily found by its weight that it cannot
confift entirely of gold ; and in fact chemi-
cal examination difcovers a confiderable
quantity of tin.   It cannot be diffolved by
the marine acid alone, but, upon the addi-
tion of a little nitrous acid, is eafily taken up:
triturated with mercury, it fcarcely unites
with it.   Thefe properties feem to indicate
that the gold has fo far received phlogifton
as to refift the marine acid, unlefs aided by
the nitrous ; but its earthy appearance, and
its habits with refpect to mercury, evince
that it is not in its complete metallic form.

3   May

May not therefore the following explanation be conformable to truth?—The solution of tin necessary for this operation must retain as much phlogiston as it possibly can, consistent with solubility. This is dropped into a solution of gold very much diluted, by which means the remaining phlogiston of the tin is more loosened, and is more easily attracted by the gold calx, which is thereby brought to a state approximating to completion, so that it can no longer be retained by the menstruum; and the same happens to the tin, by means of the dephlogistication: they must both therefore of consequence fall to the bottom, mixed intimately together. It is probable that in this case, it is the tin which prevents the union with mercury.

(E) Besides, the metals precipitate one another after a certain order. This order is found to be the same in all acid menstrua, and is mentioned in another place. This precipitation is effected by a double elective attraction (s); for the metal which is to be precipitated, exists in the solution in a calcined state; but being reduced by the phlogiston of the precipitant falls to the bottom, while at the same time the precipitant being calcined becomes soluble: but if the precipitant has been so calcined, that a part of it being insoluble is mixed with the precipitate,

(s) Treatise on Elective Attractions.

C c 2

the

the metallic fplendor is wanting, and it puts on an earthy appearance. A pure precipitate is of the fame weight as the metal had been before the folution. The mixed precipitates are lefs frequently met with, yet gold precipitated by tin exhibits one of that fort.

But many anomalous circumftances occur in this matter, depending, no doubt, upon accident. The order is indeed conftant, and never inverted : zinc prevails over iron; iron over lead; lead over tin; tin over copper; copper over filver; filver over mercury, &c.: yet it fometimes happens that a metal, which, according to the general rule, precipitates another, in its metallic ftate, from one menftrua, precipitates it from another in the form of a calx; and from a third, not at all. Some examples will illuftrate this :— zinc precipitates iron from marine acid in its metallic ftate, but from the nitrous only in the form of a calx. Perhaps the phlogifton of the zinc is not fufficient to reduce the iron, which in the latter cafe has been much more dephlogifticated; yet the particles of iron, although they were at firft metallized, may be again calcined in a menftruum which is very greedy of phlogifton. Tin, precipitated from marine acid by lead, appears in a complete form; but is not thrown down from nitrous acid; and from vinegar is precipitated in form of a calx, even by iron and zinc: lead lets fall nothing
from

from vinegar upon the addition of iron. Thefe and other anomalies will be exprefsly examined in the doctrine of attractions: it will be fufficient here to mention that a fmall excefs of acid is neceffary ; and that without it no precipitation begins (*t*): but a great fuperabundance prevents that operation, by again diffolving the precipitate ; befides, the weights of the precipitates and the diffolved precipitants do not correfpond.

§ v. *Colours of metallic Precipitates.*

Before we confider the weights of the different metals, we fhall flightly touch upon the precipitates. I employed the mineral alkali, as the degree of faturation of it with aerial acid is more conftant. When I had occafion for a cauftic alkali, I prepared it by a fmall quantity of burned lime, in a clofe bottle : the goodnefs of it was proved by its occafioning no precipitation in lime-water. The preparation of phlogifticated alkali is defcribed in another place (*u*).

(A) Gold diffolved in aqua regia is precipitated by cauftic mineral alkali, almoft black ; by the aerated, yellow ; as alfo by the phlogifticated, unlefs fome iron be prefent, which frequently happens. As the whole of the gold is fcarcely ever preci-

(*t*) This was firft obferved by the celebrated Gahn.
(*u*) Treatife on the humid Art of Affaying, § 11.

pitated,

pitated, I cannot pretend to afcertain the weights.

(B) Neither the cauftic nor aerated mineral alkali precipitate one half of platina, diffolved in aqua regia ; the precipitate is of an orange colour, which on drying changes to a brown. An over proportion of alkali re-diffolves the precipitate with a more obfcure tinge ; nay, the precipitation is fo imperfect, that alkali faturated with acid feems to diffolve it. The phlogifticated alkali does not precipitate the depurated folution, nor even make it turbid ; but heightens the colour in the fame manner as the excefs of alkali does.

(c) Silver diffolved in nitrous acid is precipitated white by aerated mineral alkali ; by the cauftic brown ; and by the phlogifticated alkali of an obfcure yellow ; by the nitrous as well as the marine acid, white ; but the former precipitate confifts of more diftinct particles, which grow black more flowly in the light of the fun.

(D) Salited mercury is precipitated red, or rather ferruginous, by aerated alkali ; by the cauftic more yellowifh, or orange. Nitrated mercury, prepared without heat, yields a ferruginous precipitate with mineral alkali ; a black with cauftic : when prepared with heat, it yields to cauftic alkali an orange, or reddifh yellow precipitate : by phlogifticated alkali it is precipitated from all acids, white ; which, when dried, becomes
of

of a brownifh yellow. Salited mercury is
very fparingly precipitated by this alkali.
The precipitate occafioned by phlogifticated
alkali is again diffolved if too much alkali
be ufed.

We have before fhewn that a white pre-
cipitate may be obtained by aerated vege-
table alkali, and have explained the caufe.

Corrofive fublimate muft be very cau-
tioufly precipitated by cauftic, as well as
aerated fixed alkali; for the part feparated
may again be diffolved by a large quantity
of water. If too much alkali be ufed, a new
compound arifes of a peculiar nature.

(E) Nitrated lead is thrown down white
by aerated, cauftic, or phlogifticated alkali.
If too much alkali be ufed, the laft precipitate
is diffolved with a brownifh yellow colour.
Vitriolated and falited lead is precipitated
white.

(F) Nitrated copper, which folution is
blue, is precipitated of a bright green by
aerated fixed alkali; by the cauftic, of a grey-
ifh brown, which grows reddifh by age. By
phlogifticated alkali, copper is precipitated of
a greenifh colour, which afterwards grows of
a brownifh red, and upon exficcation almoft
black. The aerial acid readily takes up a
fmall portion of copper during the precipi-
tation, which is again depofited by the heat
of boiling.

(G) Iron is precipitated green by the
aerated fixed alkali, from vitriolic and ma-
rine acid; this precipitate becomes of a

brownifh yellow, efpecially on exficcation :
with the cauftic alkali it approaches more
to black : in the precipitation fome part is
held in folution by the aerial acid, if the
aerated alkali be ufed : the phlogifticated
alkali yields a dark blue precipitate.

(H) Tin is precipitated white by every
alkaline falt, even by the phlogifticated al-
kali; but at length fome blue particles,
which are mixed, appear, fo that the whole,
when collected and dried, is of a light blue
colour. That thefe blue particles depend
upon iron is eafily feen upon calcination, for
they become ferruginous, and obey the mag-
net. I have always found in tin an admix-
ture of iron.

(I) Bifmuth is precipitated white by wa-
ter and alkalis, particularly the former ;
phlogifticated alkali throws down a yellow
powder, which being mixed with blue par-
ticles, occafioned by iron, at length appears
green. This yellow fediment eafily diffolves
in nitrous acid.

(K) Nickel is precipitated of a whitifh
green by fixed alkalis; by the phlogifti-
cated alkali of a yellow; and by exficcation
it is condenfed into a dark brown mafs.

(L) Arfenic diffolved in acids, which
prevent too great dephlogiftication, may, to
a certain degree, be precipitated white by the
fixed alkali, even when phlogifticated, but
the fediment is found foluble in water ; yet
nitrous acid, either alone or joined with the
marine,

marine, generally dephlogifticates the arfe-nical acid, which thereby becomes unfit for feparation. Arfenic, diffolved in marine acid, with the addition of a little nitrous acid depofited a white fediment; upon the addition of a large quantity of phlogifticated alkali, the fediment was mixed with Pruffian blue; this was diffolved in water, and freed by frequent filtration from the blue particles, and at length, on evaporating to drynefs, yielded a femipellucid mafs.

(m) Cobalt, diffolved in acids, is thrown down by fixed alkali, whether aerated or cauftic, of a reddifh blue, which colour, on exficcation, grows darker, efpecially when the former alkali has been ufed: phlogifticated alkali throws down a powder of almoft the fame colour, which, upon exficcation, becomes of a reddifh brown.

(n) Zinc is precipitated white by aerated and cauftic fixed alkali, as alfo by the phlogifticated alkali; but this laft, on exficcation, becomes of a citron colour: a fmall portion of aerial acid may eafily efcape during the precipitation.

(o) Antimony is precipitated white by alkalis, when the phlogifticated alkali is ufed; at the fame time almoft always fome blue particles are precipitated, although the regulus had been prepared without any iron. The operation fhould be cautioufly conducted, left fome part be taken up by the alkaline falt.

(p) Man-

(p) Manganese, which is procured by reduction from common magnesia nigra, generally renders menstrua brown, and with aerated alkali yields a yellowish brown sediment; with the caustic, one still darker; with the phlogisticated, a powder is separated, at first a blue one, then a white, the mixture of which renders the mass a darkish or rather a black green. That the calx of the manganese may be obtained pure and white, the precipitate occasioned by caustic alkali must be dissolved in pure vinegar; for there still remains a quantity of undissolved iron, which is taken up by the aerial acid. This acetous solution contains little or nothing of iron. That metal may also at first be separated by a small quantity of volatile alkali.

The common solution of the regulus is not perfectly precipitated by aerated alkali; and, upon the remaining liquor spontaneously evaporating to dryness, upon the glass are deposited grains of a metallic splendor, and not unlike copper. These are readily, though but partially, dissolved in nitrous acid; but upon the addition of zinc, nothing but the manganese falls, though at first it is a little reddish. With phlogisticated alkali, a yellow precipitate, like pure manganese, falls, provided the solution has deposited the iron when too much dephlogisticated by age; but the new solution yields a precipitate almost like that which

is

is obtained from common regulus. The yellow sediment may be diffolved in water.

There is always a confiderable difficulty attends the defcribing of colours, as the feveral varieties, which are almoft innumerable, are deftitute of particular names. Colours are indeed fubject to changes, but not the fmalleft ever occurs without fome determinate caufe ; they fhould therefore be carefully obferved, for from thence we fhall always learn fomething, provided we confider every thing with due attention.

§ vi. *Nature and Compofition of Metallic Precipitates.*

The metallic precipitates will reveal to us many myfteries upon proper examination.

(A) Our firft inquiry fhall be concerning their weight. I have as yet only examined thofe precipitates which are occafioned by aerated mineral alkali, cauftic alkali, and phlogifticated alkali. The refults of many of thofe experiments I have been obliged to reject, as being too vague and indeterminate; the reft I hope are fomewhat better founded. But upon confidering how difficult it is to depurate and wafh completely the metallic fediment, fo that neither the alkali, the aerial acid, the water, nor any other extraneous matter fhall adhere, I confider them only as collections of the firft terms of infinite feries,

feries, which converge very quickly.—In order to obtain the neareft poffible approximation, I repeated the experiments frequently in the moft accurate manner, and they are here fubjoined. In the following table 100 parts of the metallic regulus are always fuppofed diffolved.

100 parts

		Dry Precip. yielded
100 parts of Gold, precipitated by	aerated mineral alkali	106
	caustic	110
	phlogisticated	—
	martial vitriol	100
Platina,	aerated mineral alkali	34
	caustic	36
	phlogisticated	—
Silver,	aerated mineral alkali	129
	caustic	112
	phlogisticated	145
	falited	133
	vitriolated	134
Mercury,	aerated mineral alkali	110
	caustic	104
	phlogisticated	—
	vitriolated	119

	Dry Precip. yielded
100 parts of Lead, precipitated by aerated mineral alkali	132
caustic	116
phlogisticated	—
vitriolated	143
Copper, aerated mineral alkali	194
caustic	158
phlogisticated	530
Iron, aerated mineral alkali	225
caustic	170
phlogisticated	590
Tin, aerated mineral alkali	131
caustic	130
phlogisticated	250
Bismuth, aerated mineral alkali	130
caustic	125
phlogisticated	180
pure water	113

Nickel,	aerated mineral alkali	135
	caustic	128
	phlogisticated	250
Arsenic,	aerated mineral alkali	—
	caustic	180
	phlogisticated	160
Cobalt,	aerated mineral alkali	140
	caustic	142
	phlogisticated	193
Zinc,	aerated mineral alkali	161
	caustic	495
	phlogisticated	140
Antimony,	aerated mineral alkali	138
	caustic	138
	phlogisticated	180
Manganese,	aerated mineral alkali	168
	caustic	150
	phlogisticated	

(B) Upon

(B) Upon comparing thefe weights, a queſtion at firſt occurs concerning the caufe of fuch enormous differences; and it is plain that this caufe muſt be fought for in the precipitates themfelves. The fixed alkali, faturated with aerial acid, when added to the folution, is taken up by the more powerful menſtruum, and the weaker is of courfe expelled, and is abforbed by the calx, as it falls in greater or leſſer quantity, according to circumſtances. That this is actually the cafe is eafily demonſtrated :—let a bottle, containing a fufficient quantity of nitrous acid, be accurately weighed ; let there be put into it by degrees, *e. g.* 132 parts of lead, precipitated by aerated alkali, and not only an effervefcence will be obferved, which continues until the very laſt particle is diſſolved; but when the folution is finiſhed a deficiency of weight is difcovered, which amounts nearly to 21, and which is indubitably owing to the extrication of aerial acid (§ 111. E). But 132 — 21 = 111, a weight which ſtill confiderably exceeds that of the metal. Upon diſtillation nearly 8 of water are difcovered; there yet remain therefore 3, which by violent heat are increafed by 7 ; for 132 of the calx, well calcined, yield 110. The whole increment of weight then does not depend upon the water and aerial acid. The fame thing is evinced from the confideration of the precipitate of lead by the cauſtic alkali, as it is evident that in this cafe there
is

is no aerial acid; befides, no effervefcence accompanies the folution. If we fuppofe the quantity of water equal in both cafes, yet, even on this fuppofition, the whole excefs is not accounted for, for $116 - 8 = 108$. It is therefore probable that the matter of heat is attached to the calx. This matter of heat is always prefent in cauftic alkali; for when it is diffolved in the fimple acids, heat is always generated. This opinion is confirmed by the following confiderations: 1ft. The increment of weight can fcarce be conceived, without fuppofing an increment of matter. 2d. When the cauftic alkali is employed no other matter can be fufpected. 3d. The fame caufe is alfo prefent when the weight is increafed by dry calcination. 4th. Let the heat occafioned by the mixture of determinate portions of any acid and cauftic alkali be marked upon a thermometer: let then an equal quantity of the fame menftruum be faturated with a metal; afterwards, upon the addition of an equal quantity of cauftic alkali, it will be found either that no heat is generated, or a degree very much lefs than before. Some of the matter of heat therefore is taken up and fixed, which alfo generally makes the colours of the precipitates more obfcure, and in diftillation with fal ammoniac communicates to the volatile alkali the quantity that had been taken away. What has been faid of lead is alfo true of the other metals, a few excepted,

which feem to take up little or no aerial acid ; thefe are tin, antimony, gold, and platina.

(c) But fome precipitates *retain alfo a quantity of the menftruum.* Thus, corrofive fublimate, precipitated by aerated alkali, retains a portion of marine acid, which cannot be wafhed off by water ; but by cauftic alkali the precipitate may be obtained, either free of the acid altogether, or in a great meafure. In this cafe, as in many others, the aerial acid feems to generate a triple falt, which is fcarcely foluble. The prefence of the marine acid is eafily difcovered by nitrated filver, if the precipitate be previoufly diffolved in pure nitrous acid. Hence we obferve another difference in mercury precipitated from marine acid, according as aerated or cauftic alkali has been employed : the latter precipitate, well wafhed and put into volatile alkali, is fcarcely changed in colour; but the former inftantly grows white, generating a fpecies of fal alembroth, but containing fo litle marine acid as not to be eafily foluble in water.

The calxes, which retain any of their former menftruum, generally give over on diftillation a fmall portion of a fublimate. The mercurial calx, juft mentioned, expofed to a fufficient degree of heat, is partly reduced to crude mercury, partly to mercurius dulcis, by means of its remaining marine acid. This mercurius dulcis did not exift in the

precipitate ;

precipitate; for in that cafe it would be eafily difcovered by acids, in which it is not foluble, and would grow black with cauftic alkali, neither of which things takes place; it is therefore generated during the diftillation.

(D) The nature of phlogifticated alkali is as yet obfcure, but it poffeffes the fame properties, with regard to falts and alkaline earths, as acids when loaded with phlogifton do:—the fame is true with regard to metallic calxes, with which it forms compounds of a faline nature, though moft of them are infoluble in water.

§ VII. *Advantages refulting from the Examination of metallic Precipitates.*

In order to recommend the more accurate examination of metallic precipitates, I beg leave to add a few words concerning the advantages to be derived from that labour.

(A) It is evident that by more intimate acquaintance with thefe precipitates, the chemical theory of the operation will be better underftood.

(B) We may thereby be able to difcover the more ufeful and remarkable properties. No one is ignorant that aurum fulminans, the mineral purple, and other encauftic pigments, by which the colours of gems may be imitated, have been derived from this fource.

D d 2   (c) A

(c) A foundation is thereby laid for the art of affaying by the humid way, from the bare knowledge of the weights. It may be objected, that the doctrine of the weights is very fallacious; that they vary in the different precipitates; that by imperfect precipitation fomething remains in the liquor; and that fometimes extraneous matters are mixed with them. All this is true; but if the mode of operation be always the fame, the refults of the experiments will be conftant. Let us fuppofe that a quantity of metal (a), precipitated in a certain manner, makes a weight (b); if that fame manner be exactly employed, we may fairly conclude that a quantity of precipitate (n b), occurring in any cafe, is correfpondent to a quantity of perfect metal (n a), although in the fundamental experiment either the precipitation is incomplete, or fome extraneous matter be prefent. If all the circumftances which occafion increafe or deficiency be carefully attended to, the conclufion will remain unimpeached: let the method therefore be accurately determined, and there will be no danger of fallacy.

(D) By this the nature of metals is illuftrated. Platina, nickel, cobalt, and manganefe, are fufpected by fome perfons to derive their origin from a mixture of other metals. But if iron necefarily enters into the compofition of platina, when this is diffolved in aqua regia it fhould produce a Pruffian blue

3

upon

upon the addition of phlogifticated alkali; and this is the cafe in fact when common platina is employed, but not when it is rightly depurated (w).

If iron, adhering very obftinately to nickel, formed a great part of it, the precipitates obtained from it by alkalis could not differ from martial precipitates fo much as they do, in colour, weight, and other properties.

The fame is true of cobalt and manganefe. The regulus obtained from magnefia nigra contains about 0,08 of iron: let us fee how this affects the mixture.

100 diffolved in an acid menftruum yields to phlogifticated alkali a powder, confifting partly of blue, partly of brownifh yellow particles, which is equal in weight to 150 lb.; but 8 lb. of iron yield 48 of Pruffian blue, nearly $\frac{1}{5}$ of the whole mafs: hence it follows, that 100 parts of pure manganefe yield to phlogifticated alkali fcarcely 111, i. e. nearly fix times lefs than an equal weight of iron.

(E) Finally, it may by this means perhaps be poffible to determine the unequal quantities of phlogifton in different metals; for a given weight of precipitating metal does not yield an equal quantity of precipitate: thus, e. g. copper is able to precipitate from nitrous acid four times its own weight of filver.

(w) Treatife on Platina, § VII. (G).

DISSERTATION XXIV.

OF THE

ART OF ASSAYING

IN THE

HUMID WAY.

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§ 1. *Circumstances attending assaying by the dry Way.*

THERE is no doubt but ores were dug up, and their metallic contents extracted, long before the invention of the docimastic art; but the superior industry of later times has discovered the necessity of making trials in small, by which the quality and goodness of the ore being previously known, unnecessary expence may often be timely guarded against; and, as the great works are effected by means of fire, it was

thought

thought proper to employ the fame agent in the leffer experiments. The firft attempts certainly were extremely rude, but repeated and collected trials have gradually advanced it to the form of a fcience, or rather of an art, which although, no doubt, long concealed in the laboratory, was not publifhed until the middle of the 16th century. The firft book upon this fubject is generally attributed to Lazarus Ercker; this was publifhed in 1574. But Agricola, in his feventh Book de re Metallica, publifhed in 1576, defcribed both the inftruments and the procefles, and illuftrated them with plates. And from the preface to the Ars Docimaftica of Modeftinus Fachs, it evidently appears, that the manufcript had been prefented, in the month of March 1567, to the elector of Saxony, though it was not publifhed until after Ercker's book. In procefs of time this art became far more perfect; but we have not leifure to purfue it through its fucceffive ftates of improvement.

In the docimafia ficca three circumftances are neceffarily required;—1. *That the metal contained in the ore be all reduced to a complete form*; for fuch part of it as is deficient in that refpect, cannot be united with the eliquated metal. 2. *That the fame be collected into one mafs*; for when it is in the form of numerous fmall grains, fome of them are very eafily fcattered, and diminifh

D d 4   the

the weight. 3. *That the metallic form once induced be preferved*; for the extracted regulus muſt inevitably be diminiſhed more or leſs by calcination.

All theſe requiſites are frequently effected commodiouſly and perfectly enough by fuſion in a crucible with proper ſtrata of charcoal, provided the ore is free from ſulphur, and every other volatile mixture, and is either entirely without a matrix, or united to one which is fuſible by a moderate degree of heat; but if the matrix be refractory, notwithſtanding the moſt ſubtile pulverization it will cover many metallic particles, and thus prevent their reduction and fuſion. In this caſe it is neceſſary to employ ſuch additaments as not only promote fuſion, but occaſion ſuch a degree of tenuity as may ſuffer the reguline particles to fall to the bottom. To this they are naturally diſpoſed by their great ſpecific gravity; but, nevertheleſs, if the maſs be tenacious or thick, and eſpecially if they themſelves be ſmall and diſcrete, they are kept floating by the great friction which is to be overcome in their deſcent. Theſe additaments, which from their effect are called fluxes, are of a ſaline nature, and muſt therefore neceſſarily corrode the metals more or leſs; and hence the ſcoriæ, which are almoſt always tinged, contain a quantity of calcined metal.

But, *ſo long as we are deſtitute of a ſure method of meaſuring intenſe degrees of heat,*
and

and so long as it is necessary to perform the operation in close vessels, to prevent the access of air, so long will the force and proper continuance of the fire be, as it has hither-to been, uncertain. Now, by every ex-cess or defect in this point, somewhat of the regulus is lost; so that any judgment of the goodness of the ore, formed from the weight of the regulus, must be fallacious and uncertain, or at least somewhat inac-curate.

All this sufficiently shews, that experi-ments made in the dry way are still liable to many faults and imperfections; to which we may add some more; *viz.*—Any given quantity of ore, subjected to trial, almost always exceeds the regulus to be extracted from it very much in weight. Now, since it is almost impossible to avoid a certain loss during both calcination and fusion, this loss will be the more remarkable as the mass ultimately to be weighed becomes lighter. The case is quite otherwise with experiments made in the humid way; for here the weight of sediment, from which the quantity of the content is judged, is never less, but often greater, than that obtained by fire. Let the loss sustained in examining equal quantities of ore in both ways be the same, and denoted by (n); let the quantity of regulus, obtained by fire, be expressed by (a); that of the sediment collected in the humid way by (m a); and the true value

of

of the regulus will be a $+$ n. This being
fuppofed, as (m) is never lefs than unity, it
is obvious, that, except in cafe of equality,
n : a $>$ n : m a; and, befides, that (n) is the
more diminifhed in refpect to (m a) in pro-
portion as (m) exceeds unity the more. The
examples occurring hereafter will illuftrate
this truth more at large.

§ 11. *General Obfervations to be made in
conducting the Procefs of affaying by the
Via Humida.*

Chemiftry has at length begun to examine
the compofition of ores by means of various
menftrua; yet it muft be confeffed, that the
fragments of the humid art of affaying,
which have hitherto been publifhed, are
rather to be confidered as inftances of a
mixed method, in which the mineral ana-
lyfis is accomplifhed partly by the dry,
partly by the humid method. The metallic
part is indeed extracted by a menftruum,
but is afterwards reduced by fire. In the
following pages, however, I fhall endeavour
to point out means by which the end may
be anfwered in the humid way alone, with-
out calcination or fufion. — It is by no
means my intention to depreciate the dry
way. In practice, the moft commodious
and moft accurate proceffes ought always to
prevail; but a due comparifon of thefe two
methods can never be inftituted, nor the
beft

beſt methods of operation choſen, ſo long
as either remains clogged with difficulties
and impediments. In the proſecution of
mineral analyſis, it is therefore of the high-
eſt moment to remove theſe difficulties; for
the docimaſia ſicca conceals and confounds
many of the heterogeneous admixtures;
and if, by means of the humid way, theſe
can be all ſegregated and determined as to
quantity and quality, not only much light
will be thrown on mineralogy and metal-
lurgy, but the true foundations of theſe
ſciences laid, as any perſon who is not en-
tirely ignorant of them may readily per-
ceive. Very often it is uſeful to know, not
only the heterogeneous metallic ſubſtances,
which ſometimes, to the amount of three or
four, are mixed with the extracted regulus,
but frequently, alſo, the occult earthy ma-
trix; and yet neither of theſe can be accu-
rately diſcovered, except in a very few caſes,
by the dry method, as it has hitherto been
practiſed; for it is evident, that in fuſed
maſſes the admixtures which ought to be
removed, are the better protected by the
genuine materials in proportion as the for-
mer are more diminiſhed; a circumſtance
which cannot take place in ſolutions, which
may be diluted *ad libitum*. It muſt indeed
be confeſſed, that experiments in the humid
way often require more time, more care
and pains; but if accurate concluſions are
thereby ſupplied, we ſhould not be difficult
                                        about

about flownefs. Befides, in many cafes this method is more expeditious than the other ; and that indeed almoft always, if we are content with fuch difcoveries as can be made by the common calcinations and fufions ; nay, fometimes the dry method is obvioufly infufficient, when the metallic content is either very fmall or volatile, but particularly if it be inflammable, as is the cafe with zinc.

In the following experiments an affay cwt. was always employed, unlefs where it is exprefsly mentioned otherwife. Conclufions fufficiently accurate may indeed be often obtained from 25 lb. nay fometimes from fmaller quantities. In thefe cafes I have mentioned the ufual quantity, applying to them thofe formulæ of calculation which are founded on the mutual proportions of the proximate principles conftituting metallic falts, and which are determined in another place (a) from the weights of metallic precipitates. By an eafy fubftitution the fame formulæ may be ufed by thofe who employ $\frac{1}{4}$ or $\frac{1}{2}$ cwt.

The ores to be examined fhould be reduced to a very fubtile powder by pulverization and elutriation.

The folutions of fuch ores as contain fulphur require much caution : if poffible,

(a) See the Treatife on the Analyfis of Waters, § xi and this Treatife, § vi.

the

the vitriolic or marine acid fhould be employed ; for by continued heat the nitrous acid deftroys the fulphur : by too violent an heat, alfo, fome of it is diffipated in vapours, or is melted into globules containing heterogeneous matters ; therefore, if it can be done, boiling fhould be avoided.

All the precipitates muft carefully be wafhed, collected, dried, and weighed, as is obvious. It is fufficient here to mention this, to avoid the trouble of repetition. Diftilled water fhould conftantly be ufed, and all the menftrua carefully depurated. I call vitriolic acid diluted when its fpecific gravity is below 1,3 ; nitrous, when below 1,2 ; and the marine, when below 1,1.

The precipitations fhould be carefully made (in glafs veffels), fo that neither by the deficiency of the precipitant fhall any thing remain in the menftruum, nor by its abundance any thing be re-diffolved. The clear liquor is to be decanted from the fediment, water poured on in its place, the veffel fhaken, and then fuffered to ftand ; the water again decanted off, and frefh poured on, until it no longer can affect certain precipitants by which it muft be examined.

This being done, the fediment is to be collected upon a filter (firft weighed) made of paper not impregnated with alum, dried at firft with a gentle heat, but after expofed for five minutes in a clofe glafs veffel to 100° of heat ; upon cooling it is to be weighed, to-
gether

gether with the filter, the known weight of which muſt afterwards be ſubducted. The beſt method of waſhing the ſediment is in a bottle; for the filter, when once filled with a ſaline ſolution, is not without great diffi- culty freed from it, eſpecially if there in- tervenes a delay of ſome hours.

When I ſpeak of an alkaline precipitant, the mineral alkali, charged to ſaturation with aerial acid, is always to be underſtood.

The alkali, which is commonly called phlogiſticated, I always prepared in the ſame way — equal weights of the pureſt nitre and cream of tartar, well pulverized and mixed, are heated in the uſual way and de- tonated. The common white flux is thus procured :—half an ounce of this is diſſolved in a cucurbit, in half a quadrans of diſtilled water ; then in a digeſting heat are gradual- ly added two ounces of Pruſſian blue, care- fully avoiding ſuch an efferveſcence of the liquor as may throw any thing over, which eaſily happens if the quantity be too large : the pigment ſoon loſes its beautiful colour, not growing red but black, which evidently ſhews that a complete decompoſition has not taken place. The Pruſſian blue for ſale, is not always found of the ſame qua- lity. That which was uſed in the fol- lowing experiment, contained in 100 parts 77 of clay, and only 23 of the pigment ; ſo that if it be thought proper to employ the blue made without any alum, 221 grains will

will faturate the half ounce of alkaline falt
more completely than the two ounces above
prefcribed, and the bulk of the refiduum is
thereby alfo leffened. Whatever way the
operation be performed, after the addition of
the laft portion the whole muft be expofed
to a ftronger digefting heat, and the mafs
often ftirred with a wooden rod : if the li-
quor be too much diminifhed by evapora-
tion the defect muft be fupplied by warm
water. At length the lixivium becoming
clear, let the refiduum be collected on a
filtering paper, and gradually wafhed with
warm water until all the foluble part is fe-
parated. If the operation be rightly con-
ducted, the clear liquor amounts to an whole
quadrans, of a brownifh yellow, and fo fa-
turated as not to make paper tinged by Bra-
zil wood blue; hence the colouring prin-
ciple united to the alkaline falt feems to
be of an acid nature; but the Pruffian blue,
and other metallic precipitates of the fame
kind, always yield on diftillation, befides an
unctuous matter, a diftinct volatile alkali.

The lixivium faturated with the colouring
matter contains alfo a fmall portion of perfect
Pruffian blue, about 4 lb. to a cwt. of the
alkaline falt; which are feparated on the ad-
dition of the acid: thefe fhould be previoufly
feparated, or, what is better, corrected, by
fubducting from the weight of the fediment
16 affay pounds for each quadrans of the
lixivium. When the queftion is about a di-
ftinct

ftinct colour in the precipitate, the lixivium muſt neceſſarily be employed well depurated : thoſe who neglect this precaution, readily perſuade themſelves that any metal, precipitated by our lixivium, can put on the blue colour. But if the queſtion be only about the weight, let the lixivium, ſtill loaded with a ſmall portion of Pruſſian blue, be dropped; however, the proper correction muſt ultimately be employed; for the precipitating acid, in a ſhort time, is wont alſo to weaken the properties of the lixivium, and even to deſtroy them, eſpecially in a warm temperature. Lime, whether aerated or cauſtic, is alſo capable of abſtracting a colouring ſubſtance from iron and other metals. We ſhall perhaps ſpeak in another place more at large of the qualities and properties of theſe combinations, here we only treat of their preparation and uſe.

In the precipitating of metals by metals, it is to be obſerved, that the acid of the ſolution ought to be ſomewhat predominant ; but any more conſiderable exceſs muſt be corrected occaſionally, either by alkali, water, or ſpirit of wine.

§ III. *Ores of Gold.*

Gold occurs in the bowels of the earth native, poſſeſſing a compleat metallic form, although in general the ſmall particles of it

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are so interspersed in various matrices, that they are entirely invisible ; it is also found mineralized, that is, united with sulphur, by means of iron, or some other metal. These two species of ore we shall consider separately.

(A) Native gold is very seldom, if ever, entirely free from heterogeneous matters ; the most usual inquinaments are copper, silver, and sometimes iron. The first of these remains in the menstruum, and may be separately collected, if the gold be dissolved in aqua regia, and precipitated by martial vitriol (§ VIII.) ; the second falls during the solution, yielding a salited silver, which, washed and dried, shews the weight of the silver contained (§ V.) ; finally, the last is discovered by a phlogisticated alkali, and is estimated in a manner elsewhere described (§ IX.). The precipitate occasioned by the martial vitriol is pure gold in its metallic form, although very subtilely divided ; and therefore the weight found requires no correction.

From the preceding and following circumstances it appears, how a small portion of gold, inhering in the ores of other metals, may be extracted ; besides, a solution, containing the most minute particle of gold, instantly produces the purple precipitate of Cassius, with a solution of tin properly prepared.

(B) As to the ore which contains gold adhering to and furrounded by ftony particles, firft a determined weight is to be reduced to an impalpable powder, by triture and elutriation.

Then let the powder, weighed a fecond time, be boiled in aqua regia, fo long as any thing is taken up by the menftruum; after which let the exhaufted ore, well wafhed, be collected, exficcated to ignition, and weighed.

Let the clear folution (the colour of which in fome degree affords a method of judging) be precipitated in the ufual way by martial vitriol; the precipitate well wafhed, dried, and weighed, fhews the gold, which, added to the weight of the exhaufted ore, ought to equal the original weight, unlefs fomewhat has been difperfed by the pulverization, or unlefs fome of the matrix has entered the menftruum: the former of thefe is difcovered by comparing the weights before and after pulverization, the latter by precipitants.

When grains of gold are mixed with loofe earthy particles, they are fometimes eafily feparated by mechanical application of water.

(c) Let one or more affay cwts. of the golden pyrites, reduced to powder, be gently boiled in diluted nitrous acid, or rather digefted in an heat of 50°—80°, left the fulphur fhould be deftroyed; a gentler heat even is
neceffary

neceffary for this purpofe, that the fulphu-
reous particles, gradually feparating, may
remain in their natural ftate; for if they fufe,
the heterogeneous particles, which ought to
be removed, will be included in the fufed
mafs.

This operation muft be fo conducted, that
the menftruum may be added in feveral por-
tions, at each turn about fix times the weight
of the ore ; this attacks the pyrites with an
effervefcence, occafioned by the extrication
of a large quantity of nitrous acid.   When
this effect ceafes, another portion is to be
poured on, until the fulphur is obtained
pure, and marked with its genuine colour.
This procefs generally requires to one part
of the ore from 12 to 16 of the acid.

Let the fulphur, when wafhed, be col-
lected upon a filter, dried, and weighed :
whether it be pure or not is eafily deter-
mined by the cauftic fixed alkali.

If the matrix is infoluble in the men-
ftruum, it remains at the bottom, together
with the gold, which is diftinguifhed by its
peculiar fplendor and colour, and may be
feparated from the powder of the matrix by
careful elutriation.   The particles of gold
do not affume the form of impalpable atoms,
but of grains, very fmall indeed, but fuch
that a difcerning eye will readily obferve
their angles and inequalities ; and their ap-
pearance may perhaps lead to a fufpicion
                  E e 2   that

that they have been rather mixed with, than diffolved by the pyrites.

The clear folution is generally green; let this be evaporated to drynefs, then ignited and weighed. If there be other metals befides iron prefent, they may be extracted by fuitable menftrua; copper by the volatile alkali; manganefe, which is generally prefent, by dilute nitrous acid, with the addition of a little fugar; zinc by any menftruum, although this is fcarcely ever found in gold pyrites; and filver by pure nitrous acid. When calcareous earth forms the matrix, it unites with nitrous acid, and yields a nitrated lime; when clay, it forms an alum with vitriolic acid.

The fum of the weights of all the ingredients fhould be equal to the original weight; and, unlefs fome lofs has been fuftained during the operation, any deficiency is to be attributed to the fulphur deftroyed.

(D) I have as yet only feen one fpecimen of the ore of Nagyay; this confifts of a grey quartz, and a white matter not unlike a fandy ftone, which is taken up with effervefcence by acids, without imparting any tinge to the menftruum. The folution forms, with aerated alkali, a white precipitate, and with phlogifticated alkali a brownifh yellow. By the dry method the fame matrix foon grows black in the fire, and,

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and, according to circumſtances, tinges mi-
crocoſmic ſalt either with a purple colour,
or does not tinge it at all ; it is there-
fore (b) an aerated manganeſe. This matrix
contains diſperſed in it lamellæ of the co-
lour of lead, or a little darker, which yields
to the knife : theſe, with warm aqua regia,
grow quickly white, and are totally diſ-
ſolved with efferveſcence, tinging the men-
ſtruum yellow ; on cooling, the ſolution
depoſits acicular cryſtals. If we were pro-
vided with a ſufficient quantity of the ore,
I have no doubt but its conſtituent princi-
ples might be ſeparated in the humid way
by proper menſtrua.

§ iv. *Ores of Platina.*

So far as we know, the metal called pla-
tina is not found any where but in Ame-
rica, and is always native. The only metal
with which this is conſtantly alloyed is
iron, the greateſt part of which may be ſe-
parated by repeatedly boiling the grains of
platina, reduced to as fine a powder as poſ-
ſible, in marine acid ; in this way the ori-
ginal weight is generally diminiſhed about
0,05.
    The platina, being thus depurated, and
diſſolved in aqua regia, eaſily diſcovers itſelf

(b) Treatiſe on the White Ores of Iron, § vii.

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by means of martial vitriol, if any gold be prefent : on the other hand, if platina contains a fmall portion of gold, this may, for the moft part, be precipitated by any neutral falt, containing vegetable or volatile alkali.

§ v. *Ores of Silver.*

Silver, befides its complete form, puts on in the bowels of the earth a variety of forms, partly united with fulphur, either alone or with other metals, partly mineralized by acids.

(A) Native filver is generally allayed with gold or copper, or both ; the filver and copper are eafily taken up by nitrous acid; and if any gold be prefent, it appears at the bottom like a black powder, which by folution in aqua regia, and precipitation by martial vitriol, may be made at pleafure to affume a more metallic appearance.

This feparation being effected, the copper remaining in the liquor may eafily be collected by means of iron, or aerated alkali.

There has lately been difcovered a new variety of filver ore, which is extremely rich ; this is found in two different places, namely, at Andreafberg in Hercynia, and at Wittichen in Fuftenberg ; a fpecimen of each is to be feen in the Academy's collection. That of Fuftenberg has the appearance
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of irregular grains conglomerated, which poffefs a metallic fplendor, are a little yellow, and, together with native filver, are contained in the common white fpathum ponderofum. The grains, when examined, are found to contain filver. allayed with a fmall portion of regulus of antimony. Thefe metals may be feparated by concentrated nitrous acid; for the firft is thereby diffolved, and the latter corroded into a white calx. Aqua regia takes up the antimony, a falited filver remaining at the bottom. The particles of this ore are fomewhat malleable, and fhould be reduced as fine as poffible before they are put into the menftruum. The ore of Hercynia is called butyraceous; that which I have feen, exhibited, in a calcareous matrix, very thin leaves of metal, the fcarcity as well as tenuity of which, in the above-mentioned fpecimen, prevented me from making proper experiments; fo that I dare not abfolutely affirm that this agrees with the former in its properties, although it appears very probable.

(B) Silver united with fulphur alone is black, and is commonly called the glaffy ore of filver. Let this, divided and comminuted as much as poffible, be gently boiled for an hour in 25 cwt. of diluted nitrous acid; the liquor being decanted, let the operation then be repeated with an equal quantity of the menftruum; and unlefs the pure fulphur be now feparated, the men-

E e 4   ftruum

ſtruum is to be employed anew : the laſt particles of the ſilver adhere obſtinately to the fulphur : if any gold be preſent, it re- mains undiſſolved at the bottom.

The decanted liquors being collected, are to be deprived of the ſilver by the addition of common ſalt; let this, when collected, waſhed, and dried, be = a, and the ſilver required will = $\frac{100\ a}{129.}$

Let the fulphur be weighed ſeparately, and its weight, added to the above, ſhould amount to lb. 100, if the operation has been rightly performed, and no decompoſi- tion of the fulphur has taken place.

The clear liquor which paſſes in filtering the luna cornea, upon the addition of a phlo- giſticated alkali quickly diſcovers the fo- reign metal accidentally inhering in it : and after this precipitation the earthy contents are exhibited by a fixed alkali. The reliquiæ of the inſoluble matrix are with difficulty ſeparated from the fulphureous particles :— let the ſum of the weights be firſt enquired, then let cauſtic alkaline lixivium be poured on, and the fulphur diſſolved in a gentle di- geſting heat; the matrix then remains alone, and its weight determines that of the ful- phur. The digeſtion muſt not be continu- ed longer than is neceſſary, for the ſiliceous earth is alſo capable of entering the lixivi- um. However, this inconvenience is not very much to be apprehended, for to this

effect

effect the mechanical divifion muft be far more completely performed.

(c) Silver, united to fulphur and arfenic jointly, is generally diftinguifhed by its red colour, fometimes beautifully pellucid, re-fembling a ruby ; but it is fometimes grey, metallic, and opake. All thefe varieties however yield a red powder, and hence it is called the red ore of filver.

Let this, reduced to a very fubtile pow-der, be twice gently boiled in diluted ni-trous acid as above: a part of the menftruum being decanted off, let the white powder which remains at the bottom be well wafh-ed with diftilled water : let the filver be precipitated from the clear liquors, collect-ed by means of fea-falt ; and finally, let the falited fediment, properly treated, be weigh-ed as before.

Let the white powder above mentioned be quickly boiled in a fufficient quantity of aqua regia, until the arfenic be diffolved, and the fulphur appears pure. The yellow fo-lution, cautioufly decanted, lets fall a very white powder, upon the addition of a fuit-able portion of water ; and the fmall quan-tity which is taken up by the water is col-lected by evaporating to drynefs.

The fulphur now feparated, though it appears pure, yet ftill contains a little fil-ver, which could not eafily be feparated before by the nitrous acid, on account of the arfenic : but when the arfenic is taken away

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by the aqua regia, the remaining parts of the filver are taken up by the marine acid, entangled in fulphureous particles. In order therefore to free the fulphur from this falited filver, let cauftic volatile alkali, diluted with water, be poured on, and kept in a well-clofed veffel for fome days—a weight of the alkaline liquor equal to that of the fulphur is fufficient. The fulphur being weighed before and after the operation, indicates the weight both of itfelf and of the falited filver.

If any iron be prefent, which I have feldom experienced, it may be difcovered in the liquors firft precipitated with the falt or water, by means of phlogifticated alkali.

(D) Silver united with fulphur, arfenic, and copper, is generally called the white ore of filver, and is examined in the following manner :—let 1 cwt. of the ore, reduced to powder, be gently boiled for an hour in a little more than twelve times its weight of diluted nitrous acid. The dry powder grows black and foul ; and, when added to the acid, fends forth an hepatic fmell, a portion of it is diffolved, and at length a white refiduum remains at the bottom : upon fubfiding, if the liquor cannot be decanted clear, let it be filtered. This liquor contains the filver and the copper ; the former of thefe cannot be precipitated alone by muria, becaufe the marine acid attracts the copper more ftrongly. A white precipitate, compofed

pofed of fmall aciculæ, is indeed thrown down ; but upon expofure for fome days to the rays of the fun, does not grow black in the fmalleft degree ; and it confifts of a pe-culiar combination of marine acid, filver, and copper. The filver therefore in this cafe is to be precipitated by a determined weight of copper; and afterwards the copper to be feparated by iron or aerated alkali (§ VIII.) ; but the ultimate weight is to be diminifhed by that of fuch part of the pre-cipitant as has entered the menftruum.

Let the white refiduum be boiled in ma-rine acid, and precipitated by water ; thus we obtain the arfenic with a fmall portion of marine acid, which yet it retains obfti-nately, as is elfewhere obferved.

The arfenic being feparated, the fulphur remains alone, and muft be proved by vola-tile alkali, to try whether it ftill contains any copper or falited filver.

(E) Silver mineralized by fulphur, fome-times alfo contains antimony : this ore often forms capillary threads of an hoary brown colour : let this be gently boiled, or rather digefted, for an hour, in fix times its weight of diluted nitrous acid, until the filver is diffolved, and all the antimony reduced to a white calx, which, after decanting the li-quor, may be feparated from the fulphur by marine acid, and precipitated by water. The folution of filver is to be precipitated
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by muria, and 1 cwt. feldom contains more than four ounces.

(F) Befides fulphur and antimony, there is fometimes alfo prefent copper and iron; but the experiment in this cafe may be conduct-ed in the fame way, only with a double pro-portion of acid. Thefe metals all remain in the liquor, but are eafily feparated by preci-pitating the filver, by means of copper; and the iron by zinc, or an alkaline falt.

(G) We fometimes meet with filver mi-neralized by fulphur at the fame time con-taining iron: but in the ore which the Ger-mans call *weifertz* filver is frequently ab-fent, fo that the filver which is fometimes difcovered in it feems to be native.

(H) Silver, mineralized by the marine and vitriolic acids, is commonly known by the name of corneous ore of filver: the colour of this is white, green, yellow, violet, or black. Two remarkable varieties of it oc-cur, the one may be cut, and is fomewhat malleable; the other brittle, which, befides the acid, alfo contains fulphur.

Let 100 of the former, comminuted as much as poffible, be plunged into marine acid, and kept for one day in a digefting heat, fhaking the mixture from time to time: let the liquor be afterwards decanted clear, and the refiduum, previoufly well wafhed with water, be added to the liquor: then let nitrated terra ponderofa be gradually

dropped

dropped in, until it ceafes to occafion any precipitation. Suppofe the weight of the precipitate, wafhed and dried, $= a$; now vitriolated terra ponderofa, whofe weight is a, contains of acid 0,15 a, which corre- fponds with vitriolated filver 0,48 a; for from 100 of vitriol of filver 68,75 of metal is obtained by reduction. All the filver is not precipitated from nitrous acid by the vitriolated mineral alkali: the falited filver therefore, will be 100 — 0,48 a. In the former falt the filver contained is expreffed by 0,33 a; in the latter by 75,19 — 0,36 a, and therefore the fum required for the 100 will be 75,19 — 0,03 a. Thefe and the following formulæ depend upon the mutual proportion of the principles, and the weights of the precipitates, which are experimental- ly determined in the Tract on metallic Pre- cipitates (§ vi. A).

The brittle horny ore alfo contains ful- phur, but the faline part may be extract- ed by volatile alkali, and the quantity of filver afterwards determined by the method above mentioned (c).

(c) Artificial falited filver may, without any confider- able lofs of the metal, be reduced in the following man- ner:—let the mafs be mixed with an equal bulk of alkaline falt in a glafs mortar, and by means of a few drops of water be formed into a globule; let this globule be put into a crucible, the bottom of which has previoufly been ftrewed with fal fodæ, compreffed, and well covered with the fame alkali; an heat fufficient for fufion being then applied, the whole of the metal will be recovered if the falited filver has been accurately collected.

§ vi. *Ores*

§ VI. *Ores of Mercury.*

Mercury is afforded by nature, either native or mineralized by fulphur or acids.

(A) When native it is eafily diftinguifh-able by its fluidity, and is feldom mixed with any other metals but gold, filver, or bifmuth, which frequently exift native, and are very eafily foluble by this liquid metal; if any of thefe be prefent, the firft remains at the bottom, when the mercury is diffolved in nitrous acid; the third is indeed taken up by the menftruum, but precipitated by water; and the fecond is difcovered by fea-falt, which alfo precipitates at the fame time a falited mercury, which is eafily feparable by its greater folubility.

(B) In cinnabar the union between the fulphur and the metal feems to be more complete than in other mineralizations, as it cannot be decompofed either by vitriolic, nitrous, or marine acid. I have even attempted to difunite them by a folution of cauftic fixed alkali in water, and by boiling for many hours, but in vain. However, there are two ways of effecting a perfect decompofition; one by gently boiling for an hour the cinnabar with eight times its weight of an aqua regia, one fourth of which confifts of marine acid; the other by boiling it in marine acid, with the addition of $\frac{1}{10}$ the cinnabar's weight of black calx of

<div align="right">manganefe.</div>

manganese. In both cases the menstruum is the same, namely, a dephlogisticated marine acid; but in the first case the acid is dephlogisticated by the nitrous acid, in the latter by the calx of manganese; the former is however the best, as no heterogeneous matter is superadded.

By whatever method the metallic part of the cinnabar is dissolved, the separated sulphur may be collected by a filter, and the mercury precipitated by zinc: copper precipitates salited mercury in a more imperfect manner.

If the cinnabarine ore under examination be very much entangled in the matrix, it must be freed from it as much as mechanically can be done by lotion; then the soluble parts of the matrix taken away by nitrous, marine, or vitriolic acid, occasionally; and finally, the metal itself separated by aqua regia.

(c) Mercury has also lately been discovered mineralized (d) by the vitriolic and marine acids. The former may be separated by the help of marine acid, by trituration or digestion, and the metal precipitated by nitrated terra ponderosa; but the weight of the new earthy salt a, being given, we can easily learn the quantity of metal (as before observed § v.): yet as nitrated mercury is not totally precipitated by

(d) Mr. Woulfe was the first who discovered that these two acids act as mineralizing substances with respect to mercury.

3   vitriolated

vitriolated mineral alkali, we muſt not here
depend upon the weight of the precipitate.
By another proceſs, therefore, we obtained
from 100 of vitriol of mercury 33,899 of
pure metal, and from an equal weight of
corroſive ſublimate 75,5; from whence the
data of a calculation are eaſily deduced:
for, let the quantity of vitriolic acid $= 0,15$ a;
the vitriol of mercury containing this $=$
0,44 a; and the ſalited mercury $= 100 -$
0,44 a. In the former ſalt the mercury con-
ſtitutes 0,29 a, and in the latter $72,5 - 32$
a; ſo that the whole metallic content in 100
$= 72,5 - 03$ a. But as the ſcarcity of this
ore has not permitted us to examine it ſuf-
ficiently, we are ſtill ignorant whether the
ſalited part is to be compared with corro-
ſive ſublimate or mercurius dulcis; if the
latter, the calculation comes out different;
for in the latter of theſe two ſalts the metal
forms above 0,91, and the whole content is
exhibited by the following formula; $91,18$
$+ 0,29$ a $- 0,40$ a $= 91,18 - 0,11$ a.

§ VII. *Ores of Lead.*

Whether nature ever produces lead na-
tive is ſtill in diſpute. The moſt common
ore contains it mineralized by ſulphur, gene-
rally mixed with ſilver, ſometimes alſo with
iron and antimony together. That which
is commonly called calciform lead, contains
the

the metal united with the aerial acid, or the acid of phofphorus.

(A) Lead, if ever found native, may be eafily examined as to purity, by means of ni- trous acid, which difcovers copper both by its blue colour and its precipitation by iron; and filver is betrayed by the addition of copper.

(B) When united with fulphur, and freed from any matrix, let it be reduced to a fine powder; let this be boiled in nitrous or ma- rine acid until the fulphur is obtained pure, collected on a filter, wafhed, and dried. Its purity is afcertained by cauftic fixed alkali.

Let the folution be precipitated by aerated mineral alkali, when the lead is either alone or mixed with filver; in the former cafe, fup- pofing the weight of the precipitate $= a$, the weight of the reguline lead will be $\frac{100\,a}{132}$; if the latter, let the filver be extracted by vo- latile alkali, and the refiduum multiplied into the conftant coefficient $\frac{100\,a}{132}$ will exprefs the lead. The aerated filver is known by the diminution of weight; if this be $= b$, then the filver in a metallic form $= \frac{100\,b}{129}$.

The folution made in marine acid during the operation depofits a large quantity of falited lead, which muft be diffolved in wa- ter before the precipitation.

If antimony be prefent, this is fo much dephlogifticated by concentrated nitrous acid, that it is calcined and falls to the bot-

tom : the given weight of this, multiplied by the conſtant coefficient $\frac{100}{138}$, indicates the regulus in the muriatic ſolution; this ſpontaneouſly falls, upon dropping in water, which takes up the ſalited lead.

Iron, which yet is but ſeldom found in galena, may thus be diſcovered :—let the muriatic ſolution be firſt ſo far ſaturated with fixed alkali that the acid may predominate only a little, and yet all precipitation be ſolicitouſly avoided. This being done, the lead will be precipitated by a poliſhed plate of iron, added during boiling ; as alſo will the ſilver, which is almoſt always preſent : finally, let the iron be precipitated by aerated or phlogiſticated alkali (§ IX.); and its weight corrected by the part of the metallic plate which is diſſolved during the precipitation.

If the ore contains any matrix, this is either ſoluble, and may at firſt be ſeparated by vinegar, or elſe is inſoluble in the common acids, and is found collected at the bottom.

(c) Lead, mineralized by aerial acid, and deprived of all heterogeneous ſoluble mixture, may be diſſolved in nitrous acid, and precipitated by aerated mineral alkali; which being done, the quantity of lead is known by the weight of the precipitate, as before (B).

But if the matrix containing it be ſoluble, let the marine acid be employed,
and

and the metal precipitated by iron, as above deſcribed.

(d) Lead, mineralized by acid of phoſphorus, is eaſily diſtinguiſhed. 100 of this, in powder, is diſſolved in nitrous acid by means of heat, except a few martial particles, which generally remain at the bottom. The diſſolved lead, upon the addition of vitriolic acid, immediately forms a ſnowy white vitriol, which waſhed, collected, and dried, may be ſuppoſed to weigh a, in which caſe the correſponding lead is $= \frac{100\,a}{143}$. The liquor remaining after the precipitation yields, by evaporation to dryneſs, a phoſphoric acid.

The colour, both of this and the former ore, is owing to iron; generally they are green, ſometimes yellow, but rarely red; they occur white, and ſometimes pellucid; and all affect a cryſtalline, eſpecially a priſmatic form.

§ VIII. *Ores of Copper.*

Copper, beſides its metallic form, aſſumes a variety of ſhapes: it is generally united with ſulphur, and very ſeldom without iron; but it alſo ſometimes occurs mineralized by aerial, vitriolic, and even by marine acid.

(a) Native copper readily diſſolves in nitrous acid; if gold be preſent, it falls, untouched, to the bottom, in form of a

black

black powder; if filver, it is foon precipitated by copper; if iron, by boiling the folution for fome time, and infpiffating to drynefs, it is gradually calcined, and feparates.

(B) When mineralized by fulphur, let it be powdered and gently boiled to drynefs in five times its weight of concentrated vitriolic acid; let the refiduum be well wafhed with water, until all the metallic part has entered the menftruum.

The folution requires at leaft a portion of water equal to four times the vitriol which is to be diffolved, and therefore the quantity fhould be adapted in fome degree to the goodnefs of the ore: that which contains 0,05 of copper requires about 0,8 of water, and fo on. Let a polifhed iron plate, about twice the weight of the copper, be immerfed in the folution properly diluted; let boiling be continued until no further precipitate is occafioned. If the quantity of water be too fmall, the precipitated metal adheres very pertinacioufly to the iron plate, which, by a proper quantity, is always completely freed. Let the precitated copper, well wafhed, be fpeedily dried; but yet with fuch a degree of heat as to make the furface of the metal of different colours, which inftantly and fenfibly increafes the weight.

If the precipitated copper be found mixed with iron, which is fometimes the cafe,

2   efpecially

efpecially in the examination of a poor ore, this muft be again diffolved, to obtain a richer folution; which depofits pure copper, if the operation be conducted as above defcribed. The fame circumftance takes place in the precipitation of filver by copper; a rich folution yields the metal pure, but a poor one yields it allayed with copper.

If the copper to be precipitated contains other metals, thefe may eafily be feparated by folution in the nitrous acid. Gold remains at the bottom, undiffolved, in the form of a black powder; and filver precipitates upon a copper plate.

During this procefs, the whole, or a great part of the fulphur, flies off by the intenfe heat neceffary for evaporating the vitriolic acid to drynefs; yet its quantity may in fome degree be judged from the fum of the weights of the other ingredients, compared with the weight of the whole; befides, if thought neceffary, a folution in aqua regia may be made for the purpofe of collecting the fulphur.

(c) Copper, mineralized by aerial acid, is of an elegant green colour, and is commonly called malachites; to this alfo belongs the green filken ore of copper, which is of the fame nature. Thefe ores, when pure, are totally foluble in acids, and may be precipitated either by iron or aerated alkali. In the latter cafe, fuppofing the weight

F f 3   of

of the precipitate to be $= a$, the metallic copper contained will be $\frac{100\ a}{194}$ (i).

If calcareous earth be mixed, which sometimes happens, this may be thrown down by aerated alkali, after the precipitation of the metal by phlogisticated alkali.

Calciform blue copper consists also of copper mineralized by aerial acid. Its principles are discovered in the same way.

Calciform red copper, or of a brownish red, is called by Mr. Cronstedt the glassy ore of copper. This also is totally, or for the most part, dissolved, and that with an effervescence, though somewhat weaker than the other; so that it is doubtful whether any calciform ore of copper is entirely destitute of aerial acid. I have not seen the red pellucid ore lately discovered and described by Mr. Sage.

I have examined in many different ways the red quartz, which is supposed by Mr. Cronstedt (k) to contain such a calx. The

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(i) The illustrious Fontana was the first who determined the true nature of the malachites. He found that it contains $\frac{2}{3}$ of calcined copper, $\frac{1}{4}$ of aerial acid, and about $\frac{1}{16}$ of water. The same principles he discovered in the green silken ore, their proportions only being somewhat varied. This obtains also with respect to the blue ore; but in this the aerial acid forms a larger part of the whole, amounting nearly to $\frac{1}{3}$ or $\frac{1}{2}$; on the other hand, in the specimens which have been examined, the proportion of the water is diminished by $\frac{1}{72}$ to $\frac{1}{37}$.

(k) Mineralog. § 196. b. 2.

volatile

volatile alkali did not extract any copper,
nor did the vitriolic acid, though abstracted
to dryness. As the siliceous matrixes hard-
ly admit the menstrua, I added a portion of
the mineral fluor to the vitriolic acid; for
the fluor acid, when expelled, attacks the
quartose particles, so as to set at liberty
even the last portions of copper; but al-
though this experiment always succeeds
when copper is present, yet in the instance
of this ore not the smallest sign of that me-
tal could be discovered; and therefore it is
not without reason that we doubt of its pre-
sence.

(D) Copper, mineralized by vitriolic acid,
is no other than the common blue vitriol,
which sometimes occurs native. The cop-
per it contains is easily precipitated by iron
in the manner above described.

(E) In the collection of the Academy of
Upsal there occurs a specimen of a dilute
greenish red, friable, and of small specific
gravity, which dissolves with effervescence
in nitrous acid, imparting a green colour to
the menstruum. Upon the addition of iron
the copper is precipitated; and upon drop-
ping in a solution of silver, a white coa-
gulum is separated, being a genuine sa-
lited silver; so that no doubt can be enter-
tained of the presence of marine acid, an
opinion which is also established by the
via sicca in many ways, which I here pass
over.

F f 4   We

We find vestiges of the same acid in the beautiful green ore of Saxony, which is cubic or squamous, and has been referred to the species of mica or talc. I have lately, by favour of Mr. Werner, had an opportunity of examining a specimen intersperfed as it were with this substance. It dissolves totally in nitrous acid, and acquires a green colour : the copper is discovered by many precipitants, as by iron, by volatile and phlogisticated alkali ; but the marine acid is discovered with far more difficulty ; yet upon dropping in a solution of silver, a true luna cornea falls, but in small quantity ; there appears a portion of green scales, which did not weigh one grain ; the smallness of the quantity prevented me from making any further experiment ; but those already made put it beyond doubt that this deserves a place among the ores of copper ; it contains also a little clay, but the quantity remains to be determined by experiment on larger quantities.

§ IX.   *Ores of Iron.*

Traces of this most common of all metals are found almost every where in the mineral kingdom ; yet the ores which contain it in considerable quantity present it either mineralized by sulphur, or more or less calcined : it is rarely found united with

vitriolic

vitriolic acid ; and very feldom in a com-
plete metallic form.

(A) Mineralogifts are not yet agreed whe-
ther iron be found native. Concerning that
of Siberia, a difpute is ftill carrying on ;
and indeed it cannot be denied, but that
the cavities in the iron mafs fhew it to
have been fufed, and as it were inflated by
fpumefcence ; yet many circumftances feem
to indicate, that if this operation ever took
place, it was performed without the affiftance
of art. The ftoney matter which fills all
the cavities is of a very different nature
from the fcoriæ produced in our furnaces.
To pafs over its fituation, and other cir-
cumftances, the iron itfelf, when cold, or
moderately warm, is found to be very tena-
cious and malleable ; but when made red
hot becomes brittle, but exhibits altogether
the fame phænomena, when examined by
the via ficca, as forged iron ; with marine
acid it diffufes an hepatic odour, which evi-
dently fhews the prefence of fulphur, phlo-
gifton, and the matter of heat, as without
thefe no fuch fmell ever arifes. It is pro-
bable that the matter of heat is taken from
the fire by the metals in fufion ; yet we
cannot therefore certainly conclude, that
every thing which contains the matter of
heat has been expofed to fire : and fup-
pofing that the Siberian iron has undegone
fufion, it cannot from thence be inferred,
that this has been occafioned by art. But
this

this very rare mineral deferves to be fepa-
rately and particularly examined.

Ores of iron are frequently found in
Sweden fo perfect as to be obedient to the
magnet, nay, fometimes are themfelves
magnetic; but thefe, both with refpect to
menftrua and other properties, differ from
iron eliquated by fire. Such iron as may
properly be called native may yet be brit-
tle; for that which is extracted artificially,
and is malleable, eafily contracts brittlenefs,
but muft with menftrua preferve the fame
habits as the forged.

(B) The attractive and magnetic ores,
though they do not contain much fulphur,
yet are feldom entirely without it; but none
of it could be extracted by menftrua.

Such as are faturated with fulphur, are
called fulphureous pyrites, as nothing but
fulphur is extracted from thefe; for al-
though they fometimes contain enough of
the metal to pay the expence of eliquation,
yet the metal extracted by its brittlenefs is
rendered intractable in the fire; and, ex-
pofed to the open air, eafily falls into a ruft.

(c) Iron, mineralized by vitriolic acid,
is produced daily by the fpontaneous de-
compofition of pyrites, which is again gra-
dually fo dephlogifticated as at length to
lofe all connection with the acid. Thefe
vitriolic reliquiæ, wafhed away and depofited
in lower fituations, perhaps generate the
ores of lakes and marfhes.

(D) The

(D) The hæmatites yield a calx of iron under various forms, of an iron colour, a red, a black, or a yellow. Other ores alfo contain it, but of a lax and powdery texture, generally mixed with other earths.

Whether any of thefe ores contain iron naturally mineralized by aerial acid in the bofom of the earth, is yet unknown. Artificially, this fubtile acid is greedily taken up ; but all the natural calxes of iron hitherto examined fhew no figns of it, except the white ores of iron ; but as thefe contain aerated manganefe and calcareous earth, it is doubtful whether the martial particles contribute to furnifh any of the aerial acid extricable from thefe ores.

(E) All the ores of iron, reduced to a very fubtile powder, and repeatedly boiled in marine acid, yield up the metal. If the pyrites are more flowly diffolved, the addition of a fmall quantity of nitrous acid accelerates the operation.

The iron being extracted, the matrix, if infoluble, remains. Now, in order to obtain the metal alone, let it be all feparated by phlogifticated alkali. Suppofe the precipitate, when wafhed and dried, $= a$, then the correfponding quantity of metallic iron will be $\frac{a}{6}$; but this formula muft be corrected according to the quantity of the precipitant, as before obferved ($\S$ 11.).

That which is of itfelf foluble by means
of

of vitriolic acid, requires nothing but water to precipitate by phlogisticated alkali.

Manganese is frequently united with iron, and is discovered without difficulty by immersing the blue sediment (carefully weighed) in water sharpened by nitrous acid, by which the part arising from the manganese is dissolved, as we shall see hereafter (§ XVII.). Other methods of effecting this are described elsewhere (*l*).

Besides this metal, there are others which enter the ores of iron in still larger quantities, which for the most part render the ores useless, by imparting noxious qualities to the eliquated iron.—We shall speak of zinc, &c. and of the manner in which they are to be separated, in their proper places.

§ x. *Ores of Tin.*

Many testimonies concur in asserting that tin is found native in England; but I have never met with any specimen of it.

But the ores of tin almost always preserve the same crystalline nature, although the grains are often found so subtilely dispersed in different matrixes as entirely to elude the sight. I have lately obtained a peculiar variety found in England, which,

(*l*) Essay on the White Ores of Iron, § VIII.

consisting

confifting of contiguous fphærical ftrata, and
radii proceeding from a center, very much
refembles the brown hæmatites. In all thefe
tin is prefent, fimply calciform, and in-
volved in filiceous particles; and, fo far as
is yet known, never mineralized, either by
marine or aerial acid, or by fulphur. The
abfence of the latter is the more extraor-
dinary, as this mineralizing fubftance is pro-
duced by nature in great quantities, and is
artificially united to tin with great eafe.

(A) The examination of tin by the hu-
mid method is attended with no difficulty;
for the addition of nitrous acid quickly de-
prives it fo far of its phlogifton, as to re-
duce it all to a white calx; the iron and
copper, if any be prefent, remaining in the
liquor. 100 parts of tin, corroded by ni-
trous acid, wafhed and dried, yield 140 of
white calx: arfenic may be feparated by
wafhing the calx with large quantities of
warm water; for but little enters the acid
menftruum. The other metals are but rare-
ly united with truly native tin.

(B) The pure ore is commonly called,
according to the magnitude of its cryftals,
zinngrauffen, or *zwitter*. The examination
of thefe forms is the great difficulty of the
humid method, as they are not acted upon
effectually either by vitriolic, nitrous, or
marine acid, or by aqua regia.

The reafon of this pertinacity is, that the
calx, being well dephlogifticated, is either

not

not taken up at all, or very fparingly, and is befides involved in ftoney particles, which elude the action of the acids. The method by which this procefs feems to be moft nearly effected, is as follows :—

To a very fubtile powder of this ore, obtained not only by levigation but elutriation, let there be added a quantity of concentrated vitriolic acid, and let this be expofed to a ftrong digefting heat for feveral hours; then let there be poured on a fmall portion of concentrated marine acid, and upon agitating it a vehement effervefcence immediately begins with confiderable heat, arifing from the marine acid, which is partly deprived of its water by the vitriolic, and generates a marine acid air : by this method the forces of the two acids are conjoined. After the fpace of about an hour, let water be added, and upon fubfiding the clear liquor decanted. This operation is to be repeated with the refiduum, until the acids can diffolve no more.

What remains finally undiffolved, is nothing more than the ftoney matrix.

Let the folution, precipitated by means of aerated alkali $= a$, and the quantity of regulus fought will be $\frac{100}{131} a$.

The fubtile atoms of the cryftalline ore, intimately mixed with any matrix, may, after due pulverization, be feparated by wafhing from a given portion, as the cryftals are nearly of fix times greater fpecific
gravity

gravity than water; fo that they not only exceed the earthy particles, but the ores of other metals, and approach even to the lighter metals themfelves. The cryftalline particles, after being feparated, are expofed to the trial above-defcribed, the larger diftinct cryftals can feldom be employed; the moft common ore contains particles of them very much difperfed.

The adventitious metals ufually found in ores of tin, are copper and iron.

§ XI. *Ores of Bifmuth.*

Bifmuth, which is the moft ponderous of the femi-metals, occurs partly native, partly mineralized by fulphur, and fometimes perhaps even by the aerial acid. Some deny that this metal is found naturally united with fulphur, but without foundation; for although fuch has not yet been found in Germany, it is undoubtedly obtained in many mountains of Sweden, efpecially at Ridderhyttan in Weftmania. Calciform bifmuth is of a white colour, but it rarely occurs; fo that it cannot yet be certainly determined whether it be mineralized by aerial acid or not.

(A) Native bifmuth is eafily taken up by nitrous acid, and may then be precipitated by water; which done, if any other metals are mixed with it, they remain in the liquor,

and

and may be feparated as above-defcribed in various places.

(b) When mineralized by fulphur, it is decompofed by flight boiling in the fame menftruum; fo that the fulphur may be at laft obtained, which when wafhed and collected, is to be examined as to its purity and quantity.

The folution of the metallic part, precipitated by water, yields a white calx; let its weight $= a$, and that of the correfponding metal will be $\frac{100\ a}{113.}$.

In thefe mineralizations iron is fometimes found, which, after the feparation of the bifmuth, is eafily difcoverable.

(c) Calciform bifmuth, whether alone, or mineralized by aerial acid, alfo enters the nitrous acid, and may be precipitated by water, upon which the heterogeneous matters remain in the liquor. The prefence of cobalt is difcoverable immediately, by its communicating a red colour.

§ XII. *Ores of Nickel.*

Nickel is found, but very fparingly, mixed with other matters, yet it appears under a variety of forms; fometimes native, or united with a little fulphur, yet at the fame time intimately united with iron, cobalt, and arfenic; fo that thefe adventitious metals cannot be feparated without much difficulty,

difficulty, and the iron hitherto but imper-
fectly ; but it occurs mineralized by the vi-
triolic, and poffibly by the aerial acid.

(A) Native nickel is taken up by nitrous
acid, and when precipitated by aerated al-
kali, yields a calx which almoft always
contains iron, arfenic, and cobalt, in the
fame proportions in which they generally
accompany the regulus eliquated in the
ufual way : if filver and bifmuth happen to
be alfo prefent, which yet is very rarely the
cafe, the former is to be precipitated by
muria before the alkali is employed.

(B) If fulphur be prefent, it may be fe-
parated and collected during folution.

(c) Nickel, mineralized by vitriolic acid,
is fcarcely ever without iron ; a great part
of the martial inquinament is feparated by
long and violent boiling in water. Aerated
alkali throws down a greenifh white preci-
pitate : let the weight of this $= a$, and the
common reguline nickel is $= \frac{100\,a}{135}$.

(D) The fame metal, mineralized by ae-
rial acid, is diffolved by the nitrous acid,
and precipitated by means of aerated al-
kali.

A more compleat account of the exa-
mination of this metal, may be found in a
preceding treatife.

§ XIII. *Ores of Arfenic.*

Arfenic is produced by nature, both re-
guline, mineralized by fulphur, and calci-
form.

(A) If the purity of native arfenic is to
be examined, let it be diffolved in four
times its weight of aqua regia, and the fo-
lution flowly evaporated, without any fepa-
ration of the metal ; after this, let the ar-
fenic be precipitated by water, and collected
upon a filter ; the clear liquor which paffes
through will contain the heterogeneous me-
tals : if any filver be prefent, it feizes the
marine acid, and falls to the bottom.

Iron is fcarce ever entirely abfent, and is
frequently in fuch quantity that the mafs
appears polifhed, moft commonly cryftal-
line, and is vulgarly known by the name of
miffpickel, which is with juftice confidered
as belonging to native arfenic, as it neither
contains any fulphur, nor any mineralizing
acid.   It muft indeed be confeffed, that ar-
fenic itfelf is nothing more than a peculiar
acid coagulated by phlogifton, in a manner
fimilar to fulphur ; but the fame thing is
perhaps true of all the metals ; and befides,
the acid of arfenic, when loaded with phlo-
gifton, puts off its acid nature, and there-
fore in that cafe cannot be looked upon as
a mineralizing fubftance ; but if at any time
it

it fhall be found in the bofom of the earth, united in the manner of an acid menftruum to any metal, it then beyond doubt is to be confidered as a mineralizing fubftance.

(B) Let arfenic, mineralized by ful-phur, be diffolved in marine acid, with the addition of the nitrous occafionally, in greater or leffer quantity, fo that the ful-phur may be feparated free from all the metallic matter. The fulphur collected, wafhed, and weighed, indicates the quantity of the arfenical part; this however ought to be precipitated feparately by water, and weighed, a ftep which is neceffary wherever great accuracy is required. Salited arfenic may alfo be precipitated in its metallic form, by zinc, the folution being previoufly weakened by fpirit of wine.

When fulphur alone is united to the ar-fenic, by its different proportions it produces different colours, from a dilute yellow to an intenfe red; but if a confiderable portion of iron alfo enters the compofition, a white colour is generated, and a very different fpecies of pyrites formed, which is called the arfenical pyrites: the metallic princi-ples of this, diffolved in marine acid, or aqua regia, may be feparated in the manner above defcribed.

(c) Calciform arfenic, which nature fel-dom produces, is diffolved and examined by means of marine acid.

In

In general, concerning arfenical ores, we muft guard againft ufing too much nitrous acid, as by that the whole of the phlogifton is readily taken away, and the acid difengaged: the fmalleft quantity therefore which is fufficient for folution fhould be employed, otherwife water will occafion no precipitation ; and, notwithftanding all our caution, it is fcarce poffible to prevent the difengagement of a portion of the arfenical acid, efpecially if the boiling be long continued ; this may be recovered by evaporating to drynefs, yet rarely alone, but occafionally, and according to the laws of attraction, united either with the alkaline earths, or the metals which are prefent (m). Some of the arfenic eafily flies off.

§ xiv. *Ores of Cobalt.*

Reguline cobalt often occurs totally deftitute both of fulphur and acids, that is,

(m) Regulus of arfenic may be very commodioufly obtained in the following way, by the via ficca :—white arfenic, with three times its weight of black flux, is put into a crucible, which is covered by another, and luted fo clofely that the accefs of external air is altogether prevented. This being done, the lower crucible is gradually expofed to a red heat, and in the mean time the upper crucible is protected from the effects of the fire by means of a copper plate ; by this method, the inner furface of the upper crucible is covered with a polifhed, cryftallized, reguline cruft, which may in general be feparated whole by a gentle concuffion.

native,

native, and only mixed with other metals;
it is also found united with sulphur, and
mineralized by the acids of vitriol and ar-
senic. Nature moreover exhibits a black
calx of cobalt: it is not yet certainly known
whether it is ever loaded with the aerial
acid.

(A) When native, it almost always con-
tains iron and arsenic, and often nickel;
and hence no doubt it is, that some authors
assert that vitriolated cobalt, and the other
salts containing this metal, are of a green
colour; whereas they really are of an obscure
red, unless the nickel be in large quanti-
ty. In order to separate these metals, let
the mixture, dissolved in aqua regia, evapo-
rate to dryness, and let the cobalt be ex-
tracted by vinegar; suppose this, precipi-
tated by aerated alkali, be in weight $= a$,
then the corresponding quantity of regulus$=$
$\frac{100\ a}{160}$. We have already treated of the nickel
and the iron ($\S$ XII.); if the arsenic be su-
perabundant in the evaporated solution, it
may perhaps be precipitated by water.

(B) Cobalt united with sulphur may be
treated in the same way, as it differs from
the native cobalt only in containing a small
quantity of sulphur, which is to be separated
and collected.

(C) The celebrated Mr. Brandt has dis-
covered Cobalt joined to vitriolic acid, with
a large quantity of iron, and without any
arsenic. This I have examined in the hu-

G g 3   mid

mid way, by folution in aqua regia. The yellow folution, on account of abundant iron, was fcarce red, but by boiling af-fumed an obfcure green, and upon cooling recovered its former colour ; a property which diftinguifhes cobalt. No fulphur could be collected ; but a few drops of fa-lited terra ponderofa, diffolved in water, im-mediately difcovered the vitriolic acid. Scarce any arfenic appeared.

If in this inftance the vitriolic acid be prefent in a dephlogifticated ftate, as ap-pears to be the cafe (unlefs we rather chufe to fuppofe that a very few particles of ful-phur have been dephlogifticated during the folution) yet this acid is not prefent in fuch quantity as to give birth to a vitriolated cobalt ; for the mafs is of a metallic nature, and therefore the acid is to be confidered only as an inquinament.

The trichites of the Greeks, which is found in the mines of Herngrund and Idria, adhering to an argillaceous ftone, is found to contain fomewhat of a real cobalt, be-fides the clay and vitriolic acid ; this can be precipitated only by a phlogifticated al-kali.

(D) Cobalt frequently exhibits beautiful red efflorefcences, of a colour fometimes more dilute, fometimes more faturated ; it appears now like a loofe powder, now con-crete ; nay at times it forms moft beautiful cryftals, radiating from the fame center in the

the manner of a ftar. Thefe fubftances al-
ways fhew fome veftiges of arfenic; but
neither reguline nor white arfenic are capa-
ble of imparting the red colour to cobalt;
this can only be effected by acids. Since
therefore the colour indicates the prefence
of an acid, it is reafonable to conclude it to
be the arfenical acid. The white arfenic,
which is almoft always adhering to the ores
of cobalt, may perhaps be fometimes fo
much dephlogifticated by time, that the acid,
being extricated, is in a condition to act
upon the contiguous particles of cobalt.

In order either to eftablifh or to over-
throw this fufpicion, I thought it proper to
confult experiments. I found an exact cor-
refpondence to fubfift between cobalt, arti-
ficially faturated with acid of arfenic, and
the natural red cryftals of cobalt, except that
the latter fometimes contained white arfenic.
The arfenicated cobalt is not taken up by
water, unlefs the acid be fuperabundant;
and this it is, perhaps, which prevents the
feparation of arfenicated lime, upon the ad-
dition of falited lime to the folution; how-
ever, the event of the experiment is the fame,
whether the arfenicated cobalt employed be
natural or artificial;—on evaporating to dry-
nefs an arfenicated lime appears.

On account of the fcarcity of this fub-
ftance, I inftituted another experiment in
fmall:—I extracted the pure acid of arfenic,
firft feparating it by vitriolic acid, and then
abforbing

absorbing it by highly-rectified spirit of wine; for this last does not take up the vitriolated cobalt, but only the disengaged acid.

Natural arsenicated cobalt is scarcely soluble in water, unless the water be sharpened by an acid, and when thus dissolved it should be precipitated by aerated alkali, to discover the quantity of reguline cobalt. Cobalt, artificially arsenicated and sufficiently dried, shews the same properties as the natural.

(E) I have sometimes examined earths more or less compact, green or blue, which appear to contain a little cobalt; but in these specimens copper abounded, more especially in the blue, which also effervesce violently in acids. Let the copper be first precipitated from the solution by iron, the liquor evaporated to dryness, and the cobalt dissolved by vinegar; if any of the iron adheres to the vinegar it separates on boiling.

(F) The black calx of cobalt is generally found concreted into an hard mass, known by the name of glassy ore of cobalt; this, when pulverized, is taken up by aqua regia or marine acid, and may be examined like the former. I have not certainly discovered in these the aerial acid.

§ xv. *Ores of Zinc.*

Many still doubt whether zinc be ever found native; it is seen mineralized by sulphur

phur in the pseudo galena; by vitriolic acid, in native white vitriol; and by aerial acid, in lapis calaminaris, and in the other ores which are called glassy.

(A) If at any time native reguline zinc, without any artificial assistance, be found, its purity may be easily examined, as it is quickly dissolved in all the common mineral acids, and whatever heterogeneous metal is present may be precipitated by zinc. The factitious white vitriol rarely contains any other metal, except lead.

(B) The pseudo galena, which contains zinc mineralized by sulphur, together with iron, must be carefully treated with nitrous acid, in order to extract the metallic part without injury to the sulphur: if no other metal than iron be present, let it be precipitated by zinc; but if more, the iron must be calcined by repeatedly abstracting nitrous acid to dryness, and the new solution, made by vinegar or any other menstruum, examined.

Hepatic air is generated by the vitriolic, and still more copiously by the marine acid; but as this elastic fluid consumes a part of the sulphur, I have rather directed the employment of nitrous acid with caution in the solution of pseudo galena.

(C) Let the zinc, united with vitriolic acid, be dissolved in water, and precipitated by an aerated alkali; let the weight of
aerated

aerated be a, and that of the reguline metal zinc is $\frac{100\,a}{193}$.

If, as is generally the case, iron be present, this should be precipitated by a known weight of zinc.

(D) Zinc, mineralized by aerial acid, and dissolved in acids, should be precipitated either by aerated or phlogisticated alkali; in the latter case, or in order to determine the metallic part, the weight of the sediment must be divided by 5.

In the Treatise on Zinc we have described at large how the matrix and other heterogeneous matters are to be separated on different occasions.

A zinc, mineralized by spar, has lately been discovered (n); and I hope, by favour of the illustrious discoverer, that it will be soon examined by the humid way, as the mineralizing substance (o) is hitherto unknown.

§ XVI. Ores of Antimony.

Stibium, commonly called *antimony*, has as yet been met with only under two diffe-

(n) By Mr. Von Born.
(o) It is always extremely difficult to extract zinc from its ores in the via sicca. The ore roasted with charcoal-dust in the way described in note (m), it is true, yields several particles of zinc in the upper crucible, especially if that crucible be perforated by an hole, and covered above by another, well luted on; but hitherto it has been found impracticable to sublime more than one half of the contents of the lower crucible.

rent

 rent forms, namely native, or mineralized by fulphur.

(A) Mr. Suab, in 1748, firſt diſcovered native antimony in a calcareous matrix at Sahlberget, nor do I know that it has been found any where elſe; however, in the col-lection of the Academy, there is a ſmall piece found ſomewhere out of Sweden, but where is uncertain; this is in a quartoſe matrix: ſo that it appears native antimony is found in other places, though rarely, and though little known in this country.

The purity of the metal is moſt conve-niently examined by reducing it to a calx with ſtrong nitrous acid; for this being done, if it be entirely pure, there will re-main diſſolved in the menſtruum only a ſmall part, which ſeparates upon the addi-tion of water.

(B) The metallic part of antimony, mi-neralized by fulphur, is taken up by aqua regia, and the fulphur remains pure. The ſolution, mixed with ſtrong nitrous acid, on boiling depoſits a calcined antimony, which being ſeparated, the remaining liquor may be examined by phlogiſticated alkali, or any other means.

Sulphurated antimony, by a certain quan-tity of arſenic, grows red, frequently exhi-biting beautiful faſciculi of filaments radi-ating from a center. If arſenic be preſent it is thus diſcovered :—let the powder be gently boiled in aqua regia until the fulphur is
obtained

obtained pure; the clear folution contains the antimony and arfenic, which are feparated in the following manner :—let concentrated nitrous acid be poured on, and the antimony reduced to a white calx by boiling; let this be collected on a filter, and the liquor that paffes by evaporation yields the arfenic, generally fpoiled of phlogifton, that is, the arfenical acid.

Befides, as the cauftic alkali takes up both fulphur and antimony, this, aided by heat, may be advantageoufly employed, efpecially for the feparation of filver or other metals which do not yield to this menftruum ; an hepar is indeed generated, but in this inftance it diffolves little or nothing.

§ xvii. *Ores of Manganefe.*

The newly-difcovered femi-metal, manganefe, accompanies moft ores of iron, as has been before obferved (§ iii. c). It has however ores of its own, in which it predominates, though they are feldom to be found ; it has no where yet been obferved native, nor mineralized by fulphur, unlefs when joined with other metals in larger quantities ; it commonly occurs calciform, but under various forms ; generally alone and black, fometimes mineralized by aerial acid.

(a) Calciform manganefe alone generally poffeffes a metallic fplendor, is partly of

an

an earthy colour, black or red: the colours
are no doubt owing to unequal portions of
phlogiſton.

Let theſe ores, reduced to a ſubtile pow-
der, be immerſed in any, but particularly a
mineral acid, together with a ſmall piece of
ſugar. It is known that the calx of this
metal eludes the force of acids, unleſs ſome-
what be added to ſupply the neceſſary quan-
tity of phlogiſton. Let freſh acid be re-
peatedly poured on with ſugar, until no
more is extracted by a digeſting heat ; let
the ſolution collected be precipitated by
aerated alkali ; let the weight of the ſedi-
ment be a, and the correſponding regulus
will $= \frac{100\,a}{180}$.

· What remains undiſſolved at the bottom
either belongs to the matrix, or contains he-
terogeneous mixtures.

(B) Aerated manganeſe is rarely found
pure but in the gold mine at Nagyay: when
it forms the matrix, it is had ſcarcely mix-
ed with iron ; at leaſt, in a ſolution made
with nitrous acid, the phlogiſticated alkali
does not diſcover it. In general the iron is
in larger quantity, as in the white ores of
iron ; but theſe ores are to be treated as
before deſcribed.

In order to ſeparate the iron when it
abounds, or at leaſt the greateſt part of it, let
nitrous acid be repeatedly abſtracted to ig-
nition from the ore; after which the manga-
neſe pure, or at leaſt not much contaminat-

ed by iron, may be feparated by ftrong con-
centrated vinegar, or diluted nitrous acid.

Manganefe, precipitated from fuperabun-
dant nitrous acid, by phlogifticated alkali,
diffolves totally in diftilled water; a pro-
perty which affords a method of feparating
it from iron.

We cannot pofitively affert whether man-
ganefe, joined to marine acid, is ever found
in the bofom of the earth; although it
feems probable, on the fuppofition that na-
tural waters are fometimes found loaded
with falited manganefe (*p*).

Thus we have mentioned the fifteen me-
tals which are known to be diftinct, and
have pointed out proceffes by which the
chief varieties of their ores may be examined
in the humid way : the greater numbers of
ways by which thefe bodies can be exa-
mined the better; now one method is ne-
ceffary, now another. But I have no doubt
that multiplied experiments will difcover
methods more numerous and effective than
thofe propofed in the foregoing fketch.

(*p*) The celebrated P. J. Hjelm difcovered waters of
this fort about the lake Vettern.—Compare Mr. Scheele's
Chemical Prælections, § 189. Obf. 3.

DISSERTATION XXV.

OF THE

B L O W - P I P E;

And its Use in the Examination of Bodies, particularly Minerals.

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§ 1. *Introduction.*

THE tube which, from the uses to which it has been applied, is called the foldering tube, or blow-pipe, is very useful and necessary to many artificers; but our countryman, the celebrated metallurgist Andreas Swab, was, if I mistake not, the first who applied it to the examination of minerals, and that about the year 1738. This invention was afterwards much improved by

Messrs.

Messrs. Cronstedt, Rinman, Engestroem, Quist, Gahn, and Scheele ; nay, Mr. Engestroem has written an express treatise upon its uses, which was first published in English, afterwards translated into the Swedish, and finally the German language. The experience of many years has however shewn me, that this instrument is susceptible of further improvement, both as to construction and application : I shall therefore relate such circumstances concerning it as may be comprized in a brief description.

§ 11. *Figure of the Instrument:*

That which I use is formed of pure silver, lest it should be injured by rust ; a small addition of platina communicates the necessary hardness.

It consists of three parts, which may occasionally be joined : an handle A (tab. 2), terminating in a truncated conical apex a a, which may be, by twisting, so adapted to the aperture b as to shut it more closely than can be done by a screw. In the place of the hollow sphere which is commonly used, I make use of the little box B, formed of an elliptical plate, so bended through the centre that the opposite sides become parallel, and are joined round by a plate equal in breadth to c c : such a box collects the moisture of the breath as well as the sphere,
and

and is besides attended with the advantage of a compressed figure, and smaller circumference. The aperture (b) is somewhat conical, and hollowed out of the solid piece, and has no margin turned inwards, lest the efflux of the fluid, collected after long blowing, or the cleansing of the internal parts, should be in any degree prevented. The tube (c) is very small, and its shorter conical end (e e) exactly fitted to the aperture (f), so that no air can escape, unless through the orifice (g). Many of these tubes should be provided, with orifices of different diameters, to be applied on different occasions ; the orifice (g) itself ought to be smooth and circular, otherwise the cone of flame, hereafter mentioned, will be divided (§ 111.). The bands (h h, i i) prevent the conical apices (a a, e e) from being thurst in too far, and also serve another purpose ; for when the conical apices (a a, e e), by repeated attrition, are at last so much diminished as to fall out spontaneously, by filing away a little of the bands, they may again be made tight. The figure represents the whole apparatus of the proper size.

§ 111. *Method of blowing through the Tube.*

As it is absolutely necessary that the air should flow through the orifice in a continued stream, so long as the experiment

Vol. II.   H h   continues

continues to require it, this labour will fatigue the lungs too much, unlefs an equable and uninterrupted infpiration can at the fame time be continued. To fucceed in this operation without inconvenience, fome labour and practice are neceffary. The whole artifice, however, confifts in this, that while the air is infpired through the noftrils, that which is contained in the mouth be forced out through the tube by the compreffion of the cheeks.

To fome perfons this is extremely difficult; but frequent trials will eftablifh the habit, fo that a continual ftream of air can be fupplied for a quarter of an hour and more, without any other inconvenience than the laffitude of the lips compreffing the tube.

§ IV. *The proper Kind of Flame.*

The ftream of air above mentioned is neceffary for impelling the flame upon the matter under examination. Too great a flame does not eafily yield to the blaft; and too fmall a one produces a proportionably weak effect: a flender candle fhould therefore be chofen (either wax or tallow) (D) with a cotton wick (k l). The burned top muft be cut off at fuch a length that the remainder may be bent a little (l m). The orifice (g) is to be held above, and near to this arch, perpendicular to (l m); and the air equably expreffed.

The

The flame being forced to one fide by the violence of the blaft, exhibits two diftinct figures; the internal figure (l n), conical, blue, and well defined; at the apex of this (n), the moft violent degree of heat is excited; the external (l o), brownifh, vague, and undetermined, which is fpoiled of its phlogifton by the furrounding atmofpheric air, and occafions much lefs heat at its extremity (o) than the interior flame does.

§ v. *Proper Supports for the Matter under Examination.*

The fubftances to be examined, are fupported by two different fuftentacula, according to the diverfity of the matters under confideration; the one is charcoal of beech or fir, cut into the form of a parallelopiped; the other a filver, or (which is better) a golden fpoon, fitted with a wooden handle. The firft of thefe is generally ufed, except where phlogifton is to be avoided, or the fubject under examination is abforbed by charcoal. The golden fpoon fhould be much lefs than the figure (e), as the bulk of the fupport impedes the proper heat of the matter expofed to examination.

Particles that are very fmall and light are eafily carried off by the blaft of air; to prevent which a fmall cavity fhould be hollowed out in the charcoal, in which, be-

ing

ing partly protected by another fmaller piece
of charcoal, they may be expofed to the
apex of the flame.

§ VI. *Proper Fluxes.*

Subftances which are not fufible *per fe,*
are often fufed and diffolved by means of
falts ; I make ufe of three in particular,
one of which is acid, another alkaline, and
the third neutral.

  1. The phofphoric acid, or rather the
microcofmic falt, as it is generally called,
which contains that acid partly faturated
with mineral, partly with volatile alkali,
and loaded befides with much water, and a
gelatinous fat. This falt, when expofed to
the flame, boils and foams violently, with a
continual crackling noife, until the water
and volatile alkali have flown off ; after-
wards it is lefs agitated, fending forth fome-
what like black fcoriæ, arifing from the
burned gelatinous part ; thefe are foon dif-
pelled, and exhibit a pellucid fphærule, en-
compaffed by a beautiful green cloud, which
is occafioned by the deflagration of the phof-
phorus arifing from the extrication of the
acid by means of the inflammable matter.

  The clear globule which remains, upon
the removal of the flame continues longer
foft than that formed by borax, and there-
fore is more fit for the addition of the mat-

ter

ter to be diffolved. The volatile alkali is expelled by the fire, therefore an excefs of acid arifes in what remains, which eafily attracts moifture in a cool place.

2. The mineral alkali, or fal fodæ, which, when fufed upon charcoal, melts fuperficially, with a crackling noife, penetrates the charcoal, and difappears: this, in the fpoon, yields a permanent and tranfparent fphærule, fo long as it is kept fluid by the blue apex (n); but when the heat is diminifhed puts on a milky opacity; hence it appears why this cannot be employed upon charcoal. This alkali attacks feveral fubftances, particularly filiceous matters.

3. Cryftallized borax, expofed to the flame upon charcoal, at firft becomes opake, white, and wonderfully intumefcent; it throws out branches and various protuberances; but when the water is expelled, it is eafily collected into a mafs, which, when well fufed, yields a colourlefs fphærule, which retains its tranfparency even after cooling: if calcined borax be employed, the clear fphærule is more fpeedily obtained. This falt confifts of mineral alkali partially faturated with a peculiar acid, known by the name of fedative falt; each of its principles is feparately fufible, and each diffolves a great number of other matters.

The habits of thefe falts, when expofed to fire, being once known, it will be eafy

to

to underftand the differences occafioned by the different additions.

§ VII. *Circumftances to be obferved in the Examination of Bodies by the Blow-pipe.*

The exterior flame muft firft be directed upon the mafs under examination ; and when its efficacy is well known, then the interior blue flame.

Particular care muft be taken to obferve whether the matter decrepitates, fplits, fwells, liquefies, boils, vegetates, changes colour, fmokes, is inflamed, becomes oily, or magnetic, &c.

The piece expofed to the flame fhould fcarcely ever exceed the bulk of a grain of pepper ; but ought never to be fo fmall as not be taken up by the forceps (I) ; as, if it be too large, a part of it is neceffarily without the focus, and muft cool both the fupport and the part immerfed in the blue apex. The particles may be fufficiently commi-nuted upon the fteel plate (G) by the hammer (F), and are prevented from being difperfed by the ring (H).

A fmall piece fhould be added feparate-ly to each of the fluxes, concerning which it muft be obferved, whether it diffolves wholly, or in part only ; whether this be ef-fected with or without effervefcence ; quick-

5   ly

ly or flowly; whether the mafs be divided into a powder, or gradually and externally corroded; what colour the glafs is tinged; whether it be opake or pellucid.

These general principles fhall now be applied to exemplify the mineralogical and chemical use of the blow-pipe.

§ VIII. *Four Claffes of Foffils.*

Unorganized bodies are generally diftributed into four claffes; faline, earthy, inflammable, and metallic.

The falts are diftinguifhed by folubility and fapor: but thefe properties differ in many ways as to degree, and in fact form a continued feries with the earths; fo that the links in the chain of nature can fcarcely be diftinguifhed, unlefs artificial limits be inftituted.

Many of thefe, when expofed to the flame, eafily liquefy, or are diffolved by the water of cryftallization growing hot; but when this is expelled, fplit, and, by a more intenfe heat, are really fufed: others are deprived of their water without any motion, and are only once fufible: fome fly off by the heat.

Earths I call fuch fubftances as are fixed in the fire, not fapid, nor, though reduced to the moft fubtile powder, foluble in 1,000 times their weight of boiling water. Some

of

of thefe, either by having their furfaces in-
creafed by a previous chemical divifion, and
their furface of contact thereby increafed,
or by the affiftance of an excefs of aerial
acid, or by expofure to intenfe heat in clofe
veffels, actually are diffolved in water ; thefe
I call faline earths : but the reft, which can,
by no artifice hitherto known, be made to
enter water, deferve the name of earths fim-
ply, and *κατ' εξοχην*.   Examined by the
blow-pipe *per fe*, they are found either re-
fractory or fufible ; and very few of them
alone exhibit a tranfparent glafs.   They are
diffolved by the abovementioned fluxes, or
at leaft by one of them ; befides, they nei-
ther burn nor fmoke.

Moft of the inflammable fubftances burn,
fmoke, and yield coals loaded with an oily
matter.   Sulphureous bodies burn without
any refiduum ; but fome of thefe are only
manifefted by volatility.

The metals, excepting a few, are fufi-
ble ; the ignoble metals are calcined, and
colour the fluxes.

§ IX.   *Different Species of Salts.*

The falts, whether natural or factitious,
are very eafily examined by the blow-pipe.
Some of thefe are properly called falts, con-
fifting entirely of a foluble matter ; fuch
are acids, alkalis, and the neutrals compofed

7   of

of these; but the others, containing a base not soluble *per se,* either earthy or metallic (which is not soluble in water, unless when united with a genuine salt) may be called middle or analogical salts.

§ x. *Acids.*

The acids which are always fluid I pass over, as they elude the flame, and shall here only examine the concrete salts.

The acid of arsenic must be carefully distinguished from white arsenic, which contains this acid indeed, but unites with so much phlogiston, that it is coagulated (*a*) into a sort of sulphur. This acid, deprived of water, exhibits a dry mass; and, exposed in this state to flame upon charcoal, receives from thence so much phlogiston, as to regenerate white arsenic, and diffuse a garlic odour. In the spoon it fuses, and does not smoke, unless by the acquisition of phlogiston, either from the flame or the metallic support.

The acid, which exists molybdæna (*b*), seems to be the radix of some metal; it is of a specific gravity 3,461; possesses the property of tinging fluxes, and decomposing phlogisticated alkali.—Is this the acid of tin?

(*a*) See the Treatise on Arsenic.
(*b*) Mr. Scheele, Act. Stockholm, 1778.

This acid, expofed to the flame upon charcoal, is abforbed ; in the fpoon it emits a white fmoke, which, upon contact of the interior cone, grows of a beautiful blue ; but, expofed to the exterior cone, again grows white : it tinges microcofmic falt of an elegant green ; borax, with a fmall quantity of it, exhibits an afhen colour by reflection, but by refraction a dark violet. No other acid tinges the fluxes.

The acid of borax, commonly called fedative falt, eafily liquefies, and in the fame manner, but with far lefs intumefcence than borax : it remains fixed in a pellucid globule (§ vi.).

.The acid of tartar is not to be confounded with cream of tartar, which is partly faturated by the vegetable alkali (c) : this liquefies upon the firft contact of the exterior flame ; foon is inflated, foams, grows black, and fends forth a fmoke and blue flame, leaving a fpongy coal, which foon leaves white afhes of a calcareous nature. In order to obferve thefe changes diftinctly, the combuftion muft be occafioned flowly by the weakeft part of the flame.

Cryftallized acid of fugar is by the exterior flame firft made of an opake white, then flows, and finally foon flies off, without leaving any refiduum.

(c) Act. Stockholm, 1770.

The

The acid of phofphorus occurs in all the natural kingdoms ; when dried it is eafily fufed, and affumes the form of a pellucid globule, which yet attracts the moifture of the atmofphere.

§ XI.   *Alkalis.*

The cryftallized vegetable alkali firft becomes opake, and decrepitates long and violently, then melts into a globule which perfifts in the fpoon, but expands on the charcoal, and is abforbed with a crackling noife.

The mineral alkali has the fame properties as the fal fodæ defcribed in § VI.

The volatile alkali liquefies a little, and is diffipated.

§ XII.   *Neutral Salts.*

Several of the neutral falts flow twice, but, according to their different natures, exhibit different phænomena ; which a few examples will fufficiently illuftrate.

The decrepitating Salts.

Thefe are broken and difperfed by fudden heat : of this fort are vitriolated vegetable and volatile alkali, falited vegetable and mineral alkali.

Volatile

Volatile Salts,

Which have a bafe totally volatile, and generally fly off; vitriolated, nitrated and falited volatile alkali.

Genuine falt of amber by the exterior flame on the charcoal liquefies and fmokes; by the interior takes fire, and in burning difappears with a blue flame. In the fpoon the fame happens, except when the falt abounds with oil, which almoft always happens: in this cafe fome coaly veftiges remain. The fpurious falt of amber differs according to the frauds ufed in its preparation; it generally in the beginning fwells, fmokes, and grows black, then white; and finally, melts into a fixed white mafs.

Detonating Salts.

Thefe falts, which always abound with nitrous acid, liquefy in the fpoon, and perfift even on the charcoal, unlefs it takes fire; for when ignited they immediately take fire on the contact of phlogifton, fending forth a violent flame, with a detonating noife. During this operation the acid is diffipated, and the bafis, if fixed, remains alone. If the bafe be volatile, fcarce any detonation is excited, for the falt flies totally off.

Nitrated vegetable alkali fhews a blue flame, but the nitrated mineral and volatile alkali a yellow ore.

Carbo-

Carbonaceous Salts.

These, by the combustion of their acid, yield spongy coals, which, when ignited, soon grow white, leaving behind the alkaline base; such are acid of tartar, crude tartar, sal acetosellæ, and tartarized vegetable and mineral alkali.

Hepatiscent Salts.

These, exposed to the flame on the charcoal, flow, and yield a yellow or red mass, which diffuses an hepatic smell, especially when moistened by any acid. To this class belong all those fixed in the fire, containing vitriolic acid, which, when saturated with the phlogiston of the charcoal, generate sulphur; these are vitriolated vegetable and mineral alkali.

§ XIII. Middle earthy Salts.

Of the middle earthy salts few flow so perfectly as to be reduced to a globule, nor do they all fuse actually, though the water of crystallization in its departure excites a foam: those which contain vitriolic acid effervesce violently with borax and microcosmic salt, but are difficultly dissolved by sal sodæ.

Decrepitating Salts.

Gypsum spathosum.

Intumescent

Intumefcent Salts.

Vitriolated magnefia fwells, foams, and, when repeatedly expofed to the flame, may be fufed.

Alum is fomewhat different; for, finally, all ebullition ceafes, and the mafs remains immoveably at reft, and it undergoes no other change than to fplit: when hot it is variegated with blue fpots.

Acetated lime fwells much like alum, but fcarcely adheres to the charcoal.

Nitrated magnefia fwells with a crackling noife, but without any detonation.

Salited magnefia in a dry ftate belongs to this clafs.

Fufible Salts.

Although gypfum eluded the force of fire in Pott's furnace, yet it may be fufed in a moment, if a fection of the lamella be expofed to the blue flame: though naturally pellucid, it inftantly acquires an opacity — the water goes off without ebullition.

Carbonaceous Salts.

Tartarized lime and magnefia; nay, all the earths united with acid of tartar.

Soluble in Borax and Microcofmic Salt, with Effervefcence.

Lime, magnefia, vitriolated clay, and acetated lime.

§ XIV. Mid-

§ xiv. *Middle metallic Salts.*

Some of the middle metallic falts, either
containing a large quantity of water, or re-
taining pertinacioufly the acid, flow in the
fire, others only foam : moft of them re-
cover, at leaft partly, their metallic appear-
ance, efpecially when they touch the coal,
leaving at the fame time a fhapelefs fcoria.
By the addition of borax the fcoriæ are dif-
folved and the regulus better collected, but
here we confider the falts alone : the fluxes
are tinged in the fame way as by the metal-
lic calxes, § xxii. xxxv.

Decrepitating metallic Salts.

Nitrated lead, tartarized antimony.

Volatile metallic Salts.

To this belong the falts whofe bafe is
mercury, as they are diffipated by fire ; thofe
which contain marine acid in general fly off
more quickly than thofe which are loaded
by any other menftruum.

Detonating metallic Salts.

Silver, mercury, lead, and bifmuth, united
with nitrous acid.

Intu-

Intumescent metallic Salts.

At the first approach of fire they swell with noise, and a certain ebullition, but then remain immoveable; vitriolated and nitrated copper, iron and cobalt vitriolated, vitriolated and nitrated zinc.

Fusible metallic Salts.

These are, by the exterior flame, easily reduced to globules. By this method silver and lead salited in the spoon put on the horny appearance, but by a long violent fusion they again put it off, the acid being too much diminished : hence it appears with what caution these metals are to be made horny in the crucible.

Silver and lead vitriolated, copper and zinc salited.

Carbonaceous metallic Salt.

Tartarized antimony.

Metallic Salts tinging the Flame.

Vitriolated copper, and also nitrated copper, produces a greenness; but salited copper acts with far more efficacy. The green crystals of this first grow red by the exterior flame; they soon liquefy, and grow black; they make the flame at first of a deep blue, which afterwards verges to a green. The
flame

flame thus tinged expands much, and re-
mains so until the whole mass of the salt is
diffipated : this green salt, added to micro-
cofmic salt in fufion, immediately shews a
beautiful flame; the clear globule is tinged
green, and does not grow opake or brown,
unless a large quantity of the microcosmic
salt be added; a circumstance which takes
place much sooner upon the addition of a
smaller quantity of borax.

§ xv. *Different Species of Earths.*

Earths are in general either simple (which
I call *primitive*) and incapable of decom-
position or mutual transmutation by any
means hitherto known—of these five only
have been as yet discovered—whether a sixth
exists in the diamond we are ignorant.

Those are called *derivative* which arise
from a mixture of two or more of the
primitives. Many of those which Mr.
Cronstedt thought to be simple, I have
discovered, by the humid analysis properly
conducted, to be compound; this is not to
be objected to that great mineralogist, as the
chemical art at his time had not investigat-
ed the treasures of the mineral kingdom.

§ xvi. *Habitudes of the primitive Earths.*

Lime.

This (which by itself is infusible) by a
sufficient degree of heat loses its property of

effervefcing in acids ; it acquires folubility in water, the power of generating heat with it, and of fuffering fpontaneous calcination. Thefe laft properties however it lofes, if too much urged by heat. The heat it generates with water may eafily be tried by a drop of water on the back of the hand, with the addition of a fmall piece of lime juft cooled after burning.

Crude calcareous earth effervefces a little with mineral alkali, and is divided into fmall particles but fparingly diffolved ; when overburned it feems not to be divided or diminifhed.

In borax the former diffolves with effervefence, the latter fcarcely generates any bubbles.

In microcofmic falt the fame phænomena appear, but the effervefcence is fomewhat greater.

It is alfo obfervable that a very fmall piece of calcareous earth is eafily diffolved in borax and microcofmic falt, yielding fphærules altogether pellucid ; but if more earth be gradually added, the flux, at length faturated, retains the diffolved matter, indeed, while in perfect fufion ; but on removing the flame, the part which was taken up by means of the heat alone, feparates ; from hence clouds arife at firft, and the whole globule becomes opake, and recovers its tranfparency again by fufion. This is entirely correfpondent to what happens in the

humid

humid way : for warm water, faturated with nitre, or Glauber's falt, upon cooling is obliged to depofit that part which it had taken up in virtue of its warmth. If the fufed pellucid globule (which would grow opaque upon cooling) be quickly plunged into melting tallow, water, or other fubftance, hot (for cold generally cracks it) fo as to grow fuddenly hard, it retains its tranfparency, the particles being as it were fixed in that ftate which is neceffary to tranfparency. This is a phænomenon highly worthy of obfervation, which cannot be feen in the crucible.

Terra Ponderofa.

Terra ponderofa, expofed alone to the flame, becomes, like calcareous earth, cauftic, foluble in water, and non-effervefcent in acids.

In fal fodæ it effervefces only a little, but is fenfibly diminifhed.

In borax it diffolves with flight effervefcence.

As alfo in microcofmic falt; but here it effervefces fomewhat more violently.

The phænomena obferved on faturation with calcareous earth, have place here alfo.

Magnefia, ignited alone, lofes its aerial acid, together with the property of effervefcing in acids.

In fal fodæ it effervefces a little, but is fcarcely diminifhed.

In

In borax it diffolves with a flight effer-
vefcence.

As alfo in microcofmic falt, but with a
more violent motion.

Clay.

Common argillaceous earth abounds with
heterogeneous particles, and always con-
tains a confiderable quantity of filiceous
earth, at leaft, which generally amounts
to half; hence, when clay is required pure,
as in this inftance, the earth of alum, di-
gefted in an alkaline lixivium, and well
wafhed, muft be employed.

Expofed to the flame it grows hard, con-
tracts its bulk, but does not fufe.

In fal fodæ it effervefces a little, but is
fparingly diffolved.

In borax it diffolves with remarkable ef-
fervefcence.

In microcofmic falt a ftill more violent
ebullition takes place.

Siliceous Earth.

Alone it is not fufed.

Sal fodæ diffolves it with violent effer-
vefcence; and if the filiceous earth dif-
folved exceeds the weight of the flux, it
yields a pellucid glafs. This, and all the
other operations with fal fodæ, muft be per-
formed in the fpoon.

In borax it diffolves flowly, without any
ebullition.

5   In

In microcofmic falt very flowly, and
without effervefcence.

§ XVII. *Derivative Earths*.

To avoid confufion from multiplicity, we
fhall collect thefe into claffes, according to
their moft remarkable habits.

Decrepitating.

Spathous mineral fluor.
Lapis ponderofus (*d*).
Calcareous fpar.   Spathum ponderofum.
    The decrepitation may be performed with-
out fcattering, in a glafs tube clofed by the
finger, and held over the flame.

Infufible.

Diamond.   Pure Afbeftos *.   Refractory
clay *.   Hyacinth.   Hydrophanous filiceous
jafper.
    Lapis ponderofus.
    Pure mica *.

(*d*) This is the name given by Mr. Cronftedt (§ 209)
to a foffile, which he enumerates among the ores of iron,
and which poffeffes a peculiar fpecific gravity.   I have
attempted the analyfis of this mineral, and have difco-
vered in it lime united to a fpecies of acid hitherto un-
known ; this acid, if I miftake not, is the radix of fome
metal.   There is alfo prefent a portion of iron, which is
indeed but feldom wanting in minerals.   The fpecific gra-
vity of this acid, and its habitudes with fluxes, and phlo-
gifticated alkali, indicate its metallic nature ;—but we
fhall elfewhere treat of this matter more at large.

Quartz.
Ruby.
Sapphire. Flint. Steatite *.
Topaz.

Thofe four marked with a * are indurated by fire.

Infufible, changing Colour.

Bolar earths generally grow black—lime, mixed with aerated magnefia, black; lime, blackened by fubtle bitumen, white.

Of the gems fome change or lofe colour; thefe are, the cryfolith, topaz, and fometimes the fapphire.

The red and green jafper acquire a whitifh or grey colour.

Green, black, and red fteatite grow white.

Fufible without Ebullition.

Martial afbeftos. Augites (aqua marina*).
Bafaltes.
Chryfolith *.
Mineral fluor.
Granite.
Marga.
Petrofilex.
Emerald *.

Spathum ponderofum (this corrodes the charcoal, and acquires an hepatic tafte).

Spathum pyromachum.

Trapp.

The earths marked with a * do not, but
with

with great difficulty, fhew any figns of
fufion.

Fufible with Ebullition.

Lithomarga.
Schoerl (*e*).
Turmalin. The inflated fcoria quickly
grows white, though the ftone is b.own.
Zeolith.

*Fufible altogether in Sal Sodæ, and with
Effervefcence.*

Achates.
Chalcedony. Cornelian. Cos turcica *.
Mineral fluor *.
Onyx. Opal.
Quartz.
Common flint. Spathum ponderofum.
Thofe marked (*) effervefce but little.

*Divifible with or without Effervefcence in Sal
Sodæ, but not entirely foluble.*

Amianthus. Afbeftos.
Bafaltes.
Chryfolith * (*f*).

(*e*) I ufe the names *fchoerl* and *trapp*, which are now
known all through Europe. By *bafaltes* I underftand
larger prifms, which compofe the Giant's Caufeway,
Staffa, and other columnar mountains.

(*f*) The yellowifh cryftalline matter which fills up
the interftices of the native Siberian iron, exhibits the
fame properties with refpect to fire as the chryfolith.

I i 4 · Garnet

Garnet *.
Hornblende.
Jasper.
Lapis ponderosus. Lithomarga.
Mica. Matrix of the alum of Tolfa.
Petrosilex.
Aluminous schist. Tegular schist of Helsing. Emerald. Spathum pyromachum.
Steatites.
Talc. Trapp. Trippel. Turmalin.

Not fusible or divisible by Sal Sodæ.

Diamond.
Hyacinth.
Ruby.
Sapphire.
Topaz.

Soluble in Borax, with more or less Effervescence.

Mineral fluor *.
Marga. Mica *. Ore of Tolfa.
Aluminous schist. Tegular schist of Helsing *.
Spathum ponderosum. Schoerl.
Talc. Turmalin.
Those marked * effervesce but little.

Soluble in Borax, without Effervescence.

Achates. Diamond. Amianthus. Asbestos.
Basaltes.

                              Chalcedony.

Chalcedony. Cornelian. Chryfolith. Cos turcica.

Garnet.

Hyacinth. Hydrophanous filiceous jafper.

Lapis ponderofus. (The flux grows hardly blue ; on too much cooling it becomes white and opake).

Lithomarga.

Onyx. Opal.

Petrofilex.

Quartz *.

Ruby.

Sapphire. Common flint *. Emerald. Steatite. Spathum pyromachum.

Trapp. Trippel. Topaz *.

Zeolith.

Thofe marked * require a greater quantity of flux, and longer heat, than the reft.

Soluble in Microcofmic Salt, with more or lefs Effervefcence.

Bafaltes *.

Cos turcica.

Mineral fluor *.

Lapis ponderofus.—It effervefces at firft, then fcarcely diffolves : the flux acquires a fine blue tinge, without any mixture of rednefs. The colour is difcharged by the exterior flame, or by a fmall quantity of nitre, but is reftored by the interior flame ; if the proportion of earth be large

it

it acquires a pellucid brown colour, not dischargeable either by nitre or the flame; if still larger, it grows black and opake.

Marga. Mica *. Aluminous ore of Tolfa.

Aluminous schist. Tegular schist of Helsing *. Schoerl. Spathum ponderosum.

Turmalin*.

Those marked * effervesce but little.

Soluble in Microcosmic Salt, without Effervescence.

Agate. Diamond. Amianthus. Asbestos.

Chalcedony *. Cornelian *. Crysolith *. Granite.

Hornblende. Hyacinth. Hydrophanous siliceous jasper *.

Lithomarga.

Onyx *. Opal *.

Petrosilex.

Quartz *.

Ruby.

Sapphire. Common flint. Emerald. Steatites.

Spathum pyromachum.

Talc. Topaz. Trapp. Trippel.

Zeolith.

Those marked * are more difficultly dissolved than the rest, and scarce sensibly.

3   In

In general it is to be obferved, 1ft, that when the effervefcence is to be examined, only a very fmall piece of the matter is to be added to the flux, as the moft fubtile powder contains air, which, being expelled by the heat, forms the appearance of effervefcence. 2d, That the folution is often accelerated by lime, fpathum ponderofum, gypfum, and other additaments, both in borax and microcofmic falt. 3d, That gypfum alone is fometimes an excellent and very ufeful flux. This falt, with an equal portion of fluor mineral, is eafily reduced to a pellucid globule, which yet, upon cooling, grows white and opake. The fpathum ponderofum alfo unites with mineral fluor, but the mafs does not become pellucid.

§ xviii. *Different Species of inflammable Subftances.*

The whole theory of inflammation depends upon that fubtile principle which goes by the name of phlogifton; but this, fo far as is yet known, can never be collected pure and alone, but always requires a fuitable bafe, to which it muft be connected, in order to become manageable. Scarce any body exifts entirely deftitute of it, but a certain accumulation of it is neceffary for deflagration; this accumulation takes place in fpirit of wine, in oils, in fulphur, in
zinc,

zinc, arſenic, and perhaps in tin. It is alſo neceſſary that its connection ſhall be ſo looſe that the circumambient pure air may diſ-ſolve the union.

The dry inflammable ſubſtances, which alone are here to be conſidered, are of two kinds; viz. either coagulated and indurated oils, which are commonly called bitumens, or an acid ſaturated with phlogiſton, ſuch as ſulphur. Some of the bitumens are pure, ſuch as aſphaltus, ambergris, and amber; others reſiding in a copious earthy baſe: hence we have mountain pitch, bituminous ſchiſts, and lithanthraces.

Vitriolic ſulphur is ſeldom found alone: it readily unites with other matters, eſpe-cially metals; and hence reſult mineraliza-tions, which belong the more expreſsly to metals, as it is certain that they are very ſeldom inflammable.

§ XIX. *Habitudes of inflammable Subſtances in the Fire.*

Moſt of the inflammable ſubſtances, when expoſed to the apex of the flame, begin to liquefy, unleſs entangled in much earth, which yet does not always prevent their inflammation: when they are once inflamed let the blaſt be ſtopped until they have burned away, either alone or with a flux; and the reſiduum, if any, be examined af-terwards by the flame.

Ambergris

Ambergris burns with a white odoriferous and smoky flame; when very pure it is totally consumed by degrees, but when impure it is extinguished, leaving behind a black mass, which soon grows white by ignition, and consists partly of a calcareous powder.

Transparent amber exhibits almost the same habits, but by heat in the spoon it vanishes totally; so that this way we can hardly form any judgment concerning a residuum, which yet is easily obtained from opake amber.

Pure asphaltus burns with a smoke, and is totally consumed, without any residuum.

Mountain pitch leaves black scoriæ, shining and brittle.

Bituminous schist and lithanthraces, besides their matrix, leave an oily coal, or even spongy scoriæ, if the residuum liquefies at all.

Common sulphur readily fuses alone, and grows red; it takes fire, and is consumed with a blue flame, and a most penetrating suffocating odour.

Molybdæna contains a portion of common sulphur united to a peculiar (g) acid. This does not take fire, and upon the charcoal suffers little change; but, exposed to the flame in the spoon, it deposits a white smoke

(g) Mr Scheele, Act Stockholm, 1777.

in

in the direction of the blaft ; this fmoke, by the contact of the interior cone, grows blue, but lofes its colour by the exterior cone : it is fcarcely changed by borax and microcofmic falt, but diffolves in fal fodæ with violent effervefcence ; on fufion it grows red and tranfparent ; on cooling, di-lutely red and opake, and has an hepatic fmell.

Plumbago, another fpecies of fulphur, contains aerial acid loaded with phlogif-ton (*h*) ; on burning it fmokes, but the fmoke is only feen at the inftant the flame ceafes. It differs from molybdæna in this, that it depofits no white powder, and parti-cularly in not being taken up by fal fodæ ; it is not changed by borax or microcofmic falt.

The ores which are called inflammable, take fire difficultly ; fome of them are fcarcely changed, others are confumed or fly off, leaving the metallic calx behind.

In general the fluxes are tinged by phlo-gifton ; but unlefs this volatile principle be fixed by fome metallic calx, the tinge is eafily deftroyed by burning.

(*h*) Mr. Scheele, Act Stockholm, 1777.

§ xx. *Dif-*

§ xx. *Different Forms under which Metals appear.*

The metals are diftinguifhable from all other fubftances by their peculiar fplendor and fuperior fpecific gravity: they occur in the bofom of the earth in three different ftates, either altogether in a metallic form, in which cafe they are called *native*; or fimply deprived of phlogifton, and refembling earths, when they are denominated *calciform*; or, finally, diffolved by fulphur or acids, on which occafion they take the appellation of *mineralized*. Each of thefe forms fhall be feparately confidered.

§ xxi. *Various Habits of Metals in the Fire.*

The metals expofed to the flame do not all fhew the fame habits.

The perfect metals do not, even in the moft intenfe heat, lofe a fenfible quantity of their phlogifton; and when calcined in the humid way recover their former nature fimply by fufion.

The imperfect metals are calcined by fire, efpecially by the exterior flame, and then, in order to being reduced, indifpenfably require the contact of a phlogiftic fubftance.

With refpect to fufibility, mercury forms one extreme, as it fufes in the ordinary tempe-

temperature of the atmosphere, it cannot therefore be hardened but by artificial cold, and is always in fusion, always fluid; the rest follow in this order: tin, bismuth, lead, zinc, antimony, silver, gold, arsenic, cobalt, nickel, iron, manganese, and finally platina, which forms the other extreme, as it scarcely fuses but in the focus of a burning mirror; all these, the two last excepted, yield to the blow-pipe without any additament. Forged iron indeed is not melted without difficulty, but fused iron perfectly.

With respect to fixity, some fly off altogether, others are partly and slowly resolved into smoke.

Metals in fusion affect a globular form, and therefore easily roll off the charcoal, especially if they are of the size of a grain of pepper; therefore, either smaller pieces should be used, or they should be placed in excavations made in the surface of the charcoal. On first fusing they assume a polished surface, an appearance which the perfect metals always retain : but the imperfect are soon obscured by a calcined pellicle; for the surrounding air attracts the phlogiston with great avidity, especially when assisted by heat, which yet alone is not able to expel that principle.

The colours communicated to the calxes by fire vary.

Some of the calxes easily recover their metallic form simply by exposure to flame
upon

Pl. II
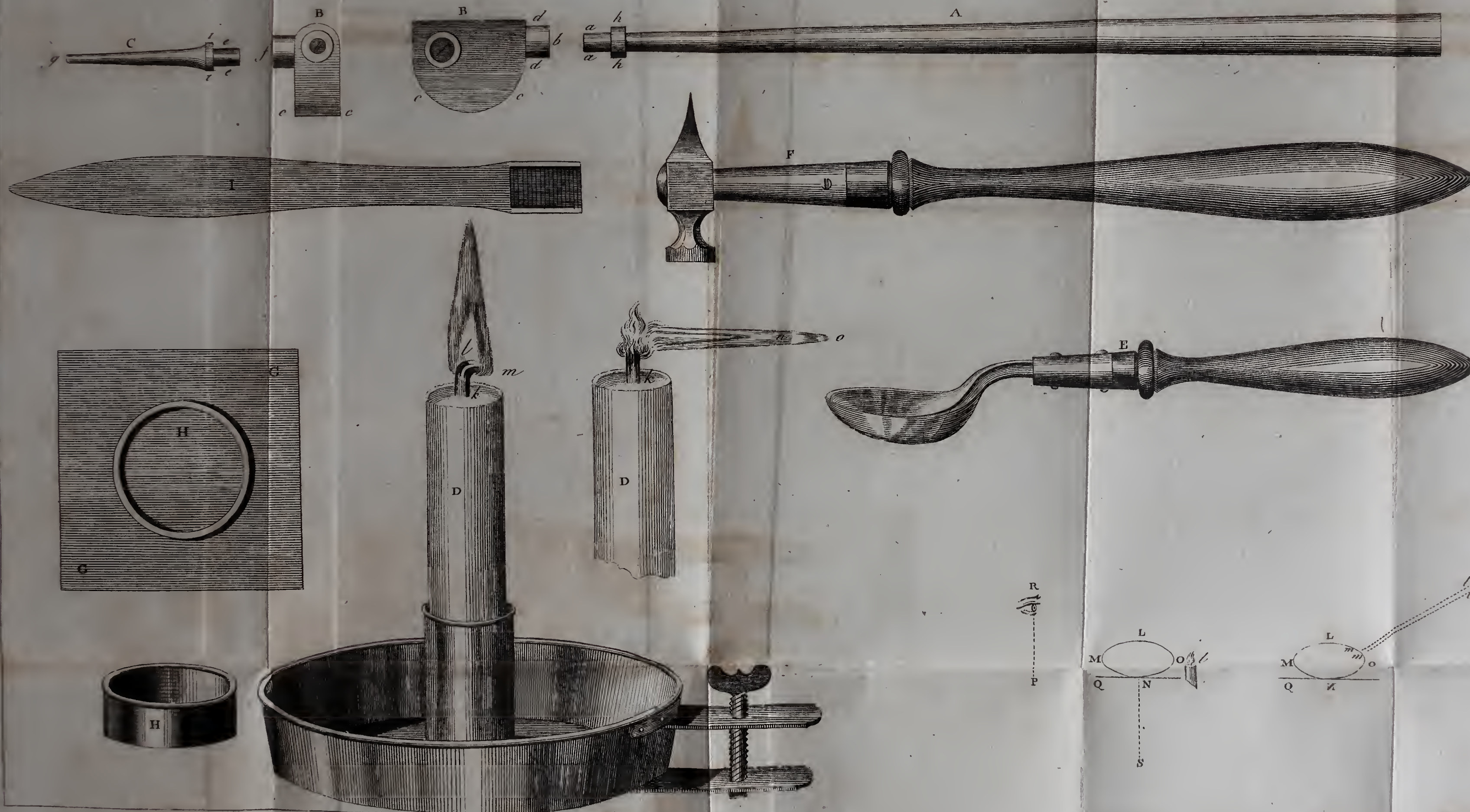
upon the charcoal; others are reduced in this way with difficulty, and fome not at all.

The reduced calxes of the volatile metals immediately fly off.

In the fpoon they exhibit nitrous globules, but it is very difficult to prevent them from being firft diffipated by the blaft.

With Fluxes.

The metals are taken up by the fluxes; but as fal fodæ yields an opake fphærule, we neglect it.

Globules of borax, upon the addition of any metallic calx, diffolve and fufe it, and, unlefs too much loaded, appear coloured and pellucid. A piece of metal calcined in the flux produces the fame effect, but more flowly.

A portion of the calx generally recovers its metallic form, and floats upon the furface, like one or more excrefcences.

In proportion as the globule is more loaded, it more readily fpreads upon the charcoal, and at length cannot be formed into a globule; for the metallic additament increafes the attraction for phlogifton.

The calxes of the perfect metals are reduced by borax in the fpoon, and adhere to it at the point of contact, and there only.

The microcofmic falt acts like borax, but does not reduce the metals; it attacks them more powerfully on account of its acid na-

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ture; at the fame time it preferves the fphæ-
rical form, and is confequently adapted in a
peculiar manner for the examination of
metals.

The tinge communicated to the flux fre-
quently varies, being different in the fufed
and the cooled globule, and that in a
double and altogether different manner; for
fome of the diffolved calxes, while fufed,
fhew no colour, but acquire one on cooling;
others, in the ftate of fluidity, have a much
more intenfe colour. If too great a concen-
tration of colour injures the tranfparency,
the globule, on compreffing it with the for-
ceps, or drawing it out into a thread, will
exhibit a thin and tranfparent mafs; but if
the opacity arifes from fuperfaturation, this
artifice will not ferve, but more flux muft
be added. No metal, unlefs calcined, com-
municates a tinge. As the fluxes attract the
metals with unequal forces, thefe laft pre-
cipitate one another.

Metals, mineralized by acids, poffefs the
properties of metallic falts; and thofe load-
ed with aerial acid that of calxes, as this
fubtile menftruum is eafily expelled with-
out any effervefcence; but when loaded with
fulphur they poffefs properties of a peculiar
kind. They may be fufed, nay calcined,
upon the charcoal, as alfo in a golden or well-
gilded filver fpoon. The volatile are dif-
tinguifhable by the fmell or fmoke, the
fixed refidua, by the particles reduced or pre-
cipitated

cipitated upon iron, or from the tinge of the fluxes. We shall now examine the more simple cafes, and treat of the more complex in another Work (*b*).

§ XXII. *Gold in a reguline State.*

Reguline gold fufes upon the charcoal, and is the only one which remains unchanged.

Calcined.

That gold may be deprived of its phlogifton in the humid way, has been already fhewn; this calx may be reduced by fire alone (§ XXI.); but that this calcination may alfo be effected by fire is feen from the ruby-coloured glafs, which may be made, even by the blow-pipe, in the following way:

To a globule of microcofmic falt let there be added a fmall piece of folid gold, of gold leaf, of purple mineral, or (which is beft) of the cryftalline falt formed by a folution of gold in aqua regia in which fea-falt is contained; let this be again fufed, and added, while yet foft, to turpeth mineral, which immediately grows red on the warm contact. The fufion being afterwards repeated, a vehement effervefcence arifes; when this is confiderably diminifhed let the blaft be ftopped for a few

(*b*) Sciagraphia Regni Mineralis.

moments,

moments, again begun, and so continued, until almost all the bubbles disappear. After this sometimes the sphærule, on cooling, assumes a ruby colour; but if this does not happen, let it be just made soft by the exterior flame, and upon hardening this tinge generally appears. If the process should fail at first, owing to minute circumstances which cannot be described, it will succeed on the second or third trial. The ruby-coloured globule, if compressed by the forceps while soft, often becomes blue; by sudden fusion it generally assumes an opal colour, which by refraction appears blue; by reflection, a brown red: but if further urged by the fire it loses all colour, and appears like water; yet the redness may be re-produced several times, by the addition of turpeth mineral.

In the same way the flux is reddened by calx of tin, in the place of the turpeth; but it has a yellowish hue, and, besides, more easily contracts opacity. The redness communicated by turpeth mineral is of a purple sort, altogether like that of a ruby.

Borax produces the same phænomena, but more rarely. It must also be observed, that the slightest variation in the management of the fires often makes this experiment fail.

As the ruby colour may also be produced by copper (§ XXVII.), a doubt may arise, whether it be the gold, or the remains of the copper (which cannot be completely separated either by antimony or nitre) which in this

this cafe produces the red colour : but it is not improbable that both metals may occa- fion the fame colour ; befides, copper is often found to contain gold.

Mineralized Gold.

Gold cannot be directly united with ful- phur ; but by means of iron, which attracts both ftrongly, they are fometimes found united into a golden pyrites : but as the quantity of gold is very fmall, a vifible globule can fcarcely be extracted by fufion and fcorification by the blow-pipe.

I have as yet had an opportunity of ex- amining the ore of Nagyay only imperfect- ly :—upon the charcoal it fmokes a little, liquefies, and finally yields a white globule, bright like filver, and malleable ;—a yellow cloud is obferved about it. Borax takes it up without effervefcence or tinge ; but mi- crocofmic falt, with effervefcence, and of a brownifh red ; but by long fufion the tinge is difcharged, and cannot be brought back, either by the exterior flame or nitre. A me- tallic globule like the former floats in the flux.

§ XXIII. *Platina.*

Native grains of platina do not at all yield to our fire, either alone or mixed with fluxes, which yet it often tinges of a green colour;

K k 3 but

but platina, precipitated from aqua regia by vegetable or volatile alkali, is reduced by microcofmic falt to a fmall malleable globule; feven or eight of thefe, flattened by the hammer, I have been able to bring together to a malleable mafs; but more only yielded a brittle one. Platina fcarcely lofes all its iron, unlefs reduced to very thin fufion; hence it eafily appears how difficult the depuration of a large mafs muft be.

§ XXIV. *Silver, reguline*.

Reguline filver eafily liquefies, and refifts calcination.

Silver-leaf, faftened to a thin glafs by means of the breath, or a folution of borax, may eafily be fixed on it by the flame, and, what is remarkable, through the glafs it appears of a gold colour; but care muft be taken not to crack the glafs.

Calcined Silver.

Calcined filver, precipitated from nitrous acid by fixed alkali, is eafily reduced.

The microcofmic falt diffolves it quickly and copioufly, but upon cooling it grows opaque, of a whitifh yellow, which is alfo fometimes the cafe with leaf-filver; if copper be prefent it is difcovered by a green colour, and fometimes by a ruby tinge, un-
lefs

lefs we rather chufe to impute that to gold. The globules can fcarcely be got pellucid, except the quantity of calx be very fmall, but with borax a longer fufion is neceffary to obtain an opacity.

The globule loaded with diffolved filver, during fufion in the fpoon, covers a piece of copper added to it with filver, and becomes itfelf of a pellucid green : antimony fpeedily takes away the milky opacity of diffolved luna cornea, and feparates the filver in diftinct grains. Cobalt, and moft of the other metals, alfo precipitate filver in the fame way as by the humid method ; i. e. a double elective attraction takes place. The metal to be diffolved remains untouched fo long as it retains all its phlogifton ; but is taken up when a fufficient quantity of that principle has fhifted to the precipitate, and reduced it.

Mineralized Silver.

Silver, mineralized by marine and vitriolic acid, yields a natural luna cornea, which upon the charcoal produces a number of fmall metallic globules : it diffolves in microcofmic falt, and renders it opake : it is reduced, at leaft partially, by borax.

Sulphurated filver (the glaffy ore of filver) fufed upon the charcoal, eafily parts with the mineralizing fubftance ; fo that a polifhed globule is often produced, which, if neceffary, may be depurated by borax : the

silver

filver may alfo be precipitated by the addi-
tion of copper, iron, or manganefe.

If arfenic be alfo prefent (as in the red
ore of filver) it muft be firft freed from the
fulphur by gentle roafting ; and finally en-
tirely depurated by borax : it decrepitates at
firft.

Copper, together with fulphur and arfenic,
mixed with filver (the white ore of filver)
yields a regulus containing the fame alloy.

Lead, loaded with fulphur and filver
(galena) is to be freed in the fame way from
the fulphur, after which the lead is gra-
dually diffipated by alternately fufing and
cooling, or is feparated in a cupel from the
filver, by means of flame. In galena I have
not yet been able to precipitate the filver
diftinct from the lead, but the whole mafs
becomes malleable : the fame is true of tin,
but the mafs is more brittle.

§ xxv. *Mercury.*

Pure mercury upon the charcoal flies off
by a moderate heat, the fixed heterogeneous
matters (if any there be) remaining behind.

When calcined it is eafily reduced and
diffipated : the fluxes take it up with effer-
vefcence, but it is foon all driven off.

I have never yet had an opportunity of
examining mercury, naturally mineralized
by acids, but this is undoubtedly volatile.
When

When loaded with fulphur it liquefies upon the charcoal, fhews a blue flame, fmokes, and gradually difappears ; but if cinnabar be expofed to the blow-pipe upon polifhed copper, the mercurial globules are fixed all around.

§ xxv.   *Lead, reguline and calcined.*

As the imperfect metals are eafily calcined, we fhall confider lead under the two forms, *viz.* reguline and calcined.

Lead readily fufes, and continues for fome time to retain a metallic fplendor; by a more intenfe heat it boils and fmokes ; hence a yellow circle is formed upon the charcoal. It communicates a fcarce vifible yellow colour to fluxes ; and when the quantity is large, the globule, on cooling, contracts a white opacity more or lefs perfect : when diffolved it is not precipitated by copper. The metals do not precipitate it from fulphur in the fame order as from acids.

Lead united to aerial acid, on the firft touch of the flame grows red ; when the heat is encreafed it flows, and is reduced to numberlefs minute globules. When united with phofphoric acid it fufes, and yields an opaque globule, but is not reduced. With fluxes it fhews the fame habits as calx of lead.

Mineralized Lead.

Sulphurated lead (galena) eafily liquefies, and,

and, being gradually deprived of the volatile part, yields a diſtinct regulus, unleſs too much loaded with iron. It may be precipitated by iron and copper.

§ XXVI. *Copper, reguline and calcined.*

A ſmall piece of copper, either ſolid or foliated, ſometimes communicates a ruby colour to fluxes, eſpecially when aſſiſted by tin or turpeth mineral (§ XII.) : if the copper be a little more or a little further calcined, it produces a green pellucid globule, the tinge of which grows weaker by cooling, and even verges to a blue. By long fuſion with borax on the charcoal (but hardly in the ſpoon) all the colour is at length deſtroyed, and can ſcarcely be re-produced by nitre, but this colour remains fixed with microcoſmic ſalt. If the calx, or metal to be calcined, during fuſion is added in conſiderable quantity, upon cooling it acquires an opake red, although, while fuſed, it is pellucid and green ; by a ſtill larger quantity it contracts opacity, even while in fuſion, and upon cooling a metallic ſplendor. Veſtiges of copper, ſo faint as ſcarcely to tinge the flux, precipitate a viſible pellicle upon a piece of poliſhed iron added to it during ſtrong fuſion, and the globule in its turn takes the colour of iron : in this way the ſmalleſt portions of copper may be diſcovered.

The

The globule made green by copper, fufed in the fpoon with a fmall piece of tin, until the colour is difcharged, yields a fphærule of tin, mixed with copper, very hard and brittle: in this cafe the precipitated metal pervades the whole of the mafs, and does not adhere to the furface.

Cobalt precipitates the calx of copper, diffolved in the fpoon by flux, in a metallic form, and imparts its own colour to glafs, which nickel cannot do. Zinc alfo precipitates it feparately, and rarely upon its own furface, as its fufion can fcarcely be avoided.

Mineralized Copper.

Copper loaded with aerial acid, at the firft touch of the flame grows black, and fufes in the fpoon: on the charcoal the lower part, which touches the ignited fupport, is reduced.

When loaded with a fuperabundance of marine acid it tinges the flame (§ XIV.); but with a fmall quantity it fhews in that way no appearance of the metal. Thus the beautiful cryftals of Saxony, which are cubic and of a deep green, do not tinge the flame; they impart to microcofmic falt a pellucid greennefs, I could not obtain with that falt an opaque rednefs, although this colour is eafily produced in a globule of borax.

Copper fimply fulphurated (afhen ore of copper) when cautioufly and gently roafted

by

by the exterior flame, finally by fufion yields a regulus furrounded by a fulphurated cruft ; the mafs, roafted with borax, feparates the regulus more quickly.

When iron is prefent, but in fmall quantity, the piece to be examined muft be firft roafted ; let it then be diffolved in borax, and tin added to precipitate the copper. The regulus may alfo be obtained by fufficient calcination and fufion, even without a precipitant, unlefs the ore be very poor.

When pyrites contain copper, though lefs than 0,01 of their weight, yet its prefence may be detected by thefe experiments in fmall : let a grain, the fize of a flax-feed, be roafted, but not fo much as to expel all the fulphur ; let it be then well diffolved by borax, a polifhed rod of iron added, and the fufion continued until the furface, when cooled, lofes all fplendor. So much borax is required as will be fufficient to make the whole of the fize of a grain of hemp-feed. Slownefs of fufion is injurious, and by too great tenuity the precipitation is retarded ; this may be corrected by the addition of a little lime : too much calcination is inconvenient, for by this the globule forms flowly, is fomewhat fpread, becomes knotty when warm, corrodes the charcoal, deftroys the iron, and the copper does not precipitate diftinctly ;—this defect is amended by a fmall portion of the crude ore.

When

When the globule is properly fufed, as directed, immediately upon ftopping the flame let it be thrown into cold water, in order to break fuddenly : if the cupreous content be lefs than 0,01, one end of the wire only is covered with copper, which otherwife would be entirely covered.

The celebrated Gahn, who has examined copper ores with peculiar accuracy, has another method of difcovering the fmaller traces of that metal; namely, a grain of the ore, well freed from fulphur by calcination, is expofed to the action of the flame, driven fuddenly upon it, *per vices*; and at thefe inftants a cupreous fplendor appears upon the furface, which otherwife is black ; and this fplendor is the more quickly produced, in proportion as the ore is poorer.

Cupreous pyrites on roafting tinges the flame green.

§ XXVII. *Iron, reguline and calcined.*

Forged iron is calcined, but can fcarcely be fufed, and when fufed liquefies.

Forged iron cannot be fufed by borax; it fufes in microcofmic falt, but is rendered brittle.

Calcined iron, by heating on the charcoal, becomes magnetic—in the fpoon it fufes.

The fluxes grow green with this metal ; but in proporton as the phlogifton is more

I   deficient

deficient they grow more of a brownish yel-
low : on cooling the tinge is much weaken-
ed ; nay, when originally weak, entirely va-
nifhes. By too much faturation the globule
becomes black and opake.

The fulphureous pyrites may be collected
into a globule by fufion, and is firft fur-
rounded by a blue flame ; but as the me-
tal is eafily calcined, and changes into black
fcoriæ, neither by itfelf, nor with fluxes,
does it exhibit a regulus ;—on roafting it
grows red.

§ xxviii. *Tin, reguline and calcined.*

Tin eafily liquefies, and is calcined.

The fluxes diffolve the calx fparingly ;
and, when faturated, contract a milky opa-
city. Some flight veftiges of this metal,
diffolved in any flux, may be diftinctly pre-
cipitated upon iron.

Cryftallized ore of tin, urged by fire upon
the charcoal, yields its metal reduced.

§ xxix. *Bifmuth, reguline and calcined.*

Bifmuth has nearly the fame habits as
lead ; the calx is reduced upon the coal,
it is fufed in the fpoon.

The calx, diffolved in microcofmic falt,
yields a brownifh yellow globule, which
grows

grows more pale upon cooling, at the fame time lofing fome of its tranfparency : by too much calx a perfect opacity is produced.

A fimilar mafs is obtained with borax in the fpoon ; but on the coal a grey one, which can fcarcely be freed from bubbles. On fufion, the glafs fmokes, and forms a cloud about it.

Bifmuth is eafily precipitated by copper and iron.

Mineralized Bifmuth.

Sulphurated bifmuth is eafily fufed, exhibiting a blue flame and a fulphureous fmell. Cobalt, when added, by means of the fulphur, enters the globule ; but the fcoria foon fwells into diftinct partitions, which, further urged by fire, exfudes globules of bifmuth.

Sulphurated bifmuth, by the addition of borax, may be diftinctly precipitated by iron or manganefe.

§ xxx. Nickel, reguline and calcined.

The regulus of nickel fufed is indeed calcined, but more flowly than other metals.

The calx imparts to fluxes an hyacinthine colour, which on cooling grows yellow,

7 and

and by long-continued fire may be deftroy-
ed ; if the calx of nickel is contaminated by
ochre of iron, the latter is firft diffolved.
Nickel diffolved is precipitated on iron,
nay on copper—an evident proof that it does
not originate from either of thefe metals.

Mineralized Nickel.

Sulphurated nickel is no where found
without iron and arfenic : the regulus is
obtained by roafting, and fufing with borax,
though it ftill remains mixed with fome
other metals.

§ xxxi. *Arfenic, reguline and calcined.*

Regulus of arfenic kindles by a fudden
heat, and not only depofits a white fmoke
on the charcoal, but diffufes the fame co-
pioufly all around. The calx fmokes with a
garlic odour, but cannot burn.

By a proper quantity the fluxes grow yel-
low, without opacity ; and by a long-conti-
nued fire the volatile additament is difpelled.
Iron and copper precipitate this femi-metal
under a metallic form, which gold is not
able to do.

Yellow arfenic liquefies, fmokes, and to-
totally flies off : when heated by the ex-
terior flame, fo as neither to liquefy nor
fmoke, it grows red, and again, upon cool-
ing,

ing, yellow; if it only begins to fufe, it acquires a red colour, which remains after cooling. Realgar liquefies more eafily, and is befides totally diffipated.

§ XXXII. *Cobalt, reguline and calcined.*

The regulus of cobalt fufes, and may partly be depurated by borax, for the iron is firft calcined and taken up. The fmalleft portion of the calx tinges the flux of a deep blue, which yet, when feen by refraction, appears violet: this colour is very pertinacious in the fire. Cobalt is precipitated upon iron from the blue globule, but not upon copper.

When calx of iron is mixed with that of cobalt in a flux, the former is diffolved.

Mineralized Cobalt.

Cobalt, in fufion, takes up about one third of its own weight of fulphur, but then affumes fo refractory a nature, that it can fcarcely be fufed. Iron, copper, and feveral other metals, precipitate cobalt.

The common ore, by roafting and fufion, yields a regulus, though an impure one.

The green cobalt, which I have hitherto examined, tinges the microcofmic falt indeed of a blue, but at the fame time fhews red fpots indicating copper.

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§ XXXIII. *Zinc, reguline and calcined.*

Fufed zinc takes fire, fending forth a lanuginous white calx, which foon extinguifhes the beautiful bluifh green flame; but if the reguline nucleus, included in this lanuginous matter, be urged by the fire, it is inflamed now and then, but flies about, and as it were explodes.

When added to borax, it excites a fpumefcence, and at firft tinges the flame; it continually diminifhes, and the flux fpreads upon the charcoal: but in fufed microcofmic falt it not only occafions fpumefcence, but fends forth feveral flafhes, with a crackling noife. By too great heat it explodes, fending forth ignited particles.

The white calx, expofed to the flame on the charcoal, puts on a yellowifh fplendor, which, when the flame ceafes, vanifhes—it remains fixed and refractory. The fluxes are fcarely tinged, but when faturated by fufion, on cooling grow opake and white. Around the globules clouds appear, which are of a nature fimilar to that of the metallic calx.

Diffolved zinc is not precipitated by any other metal.

That zinc which contains aerial acid has the fame properties as calcined zinc.

In the pfeudo galenæ fulphur is prefent by means of iron. Thefe in general (upon the

7   charcoal)

charcoal) fmell of fulphur, fufe, and tinge the flame more or lefs, depofiting a cloud all around. The fluxes diffolve; thofe which have no matrix are tinged by thofe which contain iron, and by faturation acquire a white opacity, which verges to brown or black, according to the variety of compofition.

§ XXXIV. *Antimony, reguline and calcined.*

Regulus of antimony, fufed, and ignited upon the charcoal, affords a beautiful object; for if the blaft of air be fuddenly ftopped, a white fmoke rifes copioufly and perpendicularly, while in the mean time the inferior part round the globule is condenfed into cryftalline fpiculæ, analogous to thofe which are commonly called argentine flowers.

The calx tinges fluxes of an hyacinthine colour, but on fufion fmokes, and is eafily diffipated, efpecially on the charcoal; yet it alfo there depofits a cloud.

The diffolved metal may be precipitated by iron and copper, but not by gold.

Mineralized Antimony.

Crude antimony liquefies upon the charcoal, fpreads, fmokes, penetrates it, and in conclufion difappears totally, except a ring which it leaves behind.

L l 2   § XXXV.

§ xxxv. *Manganese, reguline and calcined.*

The regulus of manganese scarcely yields to the flame; for a small particle is easily calcined, and a large one cannot be made sufficiently hot.

The black calx imparts a bluish red colour to the fluxes; the tinge of borax, unless well saturated, is more yellow. The colour may be gradually altogether destroyed by the interior flame, and again re-produced by a small particle of nitre, or the exterior flame alone; these changes may be alternated *ad libitum.*—The cause of this is elsewhere explained.

When loaded with aerial acid it is of a white colour, which by ignition is soon changed to a black.—In other respects this shews the same phænomena as the black calx.

§ xxxvi. *Conclusion.*

From what has been said I think it apparent, that the blow-pipe is an instrument extremely useful, nay necessary, to chemists; for many experiments are daily neglected, 1st, Because they require furnaces, and a large apparatus of vessels;—yet many of these may easily be performed by means of the apparatus above described: 2d, From the want of time necessary for examining in the
ordinary

ordinary way ;—whereas the experiments above mentioned may be finished in a few minutes : 3d, The usual method of examination requires a certain quantity of the matter to be examined, which prevents the examination of such as are scarce or dear ; —but in our way the smallest particle is sufficient.

However, the conveniencies now described, though of great weight, are attended with this defect, that they do not determine the proportions, or at least point them out but very inaccurately, and therefore are not to be preferred to the larger trials, unless when time or other circumstances prevent them. But the first enquiry to be made is, what a substance contains, not how much : and I have learned, by the experience of many years, that these trials in small suggest the proper method of instituting experiments at large. These experiments have besides some advantages over those conducted in crucibles, *viz.* we can see all the phænomena from beginning to end, which wonderfully illustrates the series of operations, and their causes (§ XXI. XXX.—XXXV.). Experiments made in crucibles are often fallacious, as the substance of the vessel itself is corroded. —We suppose that lime or magnesia, melted with fixed alkali, are united with it in the way of solution ; but the globule, when well fused in the spoon, by its transparency permits us plainly to see that, except the
<div align="right">siliceous</div>

filiceous part, it is only mechanically mixed (§ xvi.). The moft intenfe degree of heat may in this way be obtained in a few minutes, which is fcarcely obtained in many hours in a crucible (§ xiii. xxiii.).

This may be fufficient for the commendation of the blow-pipe;—thofe who ufe it will gradually difcover more of its valuable properties.

END OF THE SECOND VOLUME.